MEMOIRS

OF THE

NATIONAL MUSEUM
OF VICTORIA

MELBOURNE

(WORLD LIST ABBREV. MEM. NAT. MUS. VIC.)

No. 20

Issued January, 1956

R. T. M. PESCOTT, M.Agr.Sc., F.R.E.S., M.I.Biol.
DIRECTOR

PUBLISHED BY ORDER OF THE TRUSTEES

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PAGE

TABLE OF CONTENTS

NORTH-WEST AUSTRALIAN ROCK PAINTINGS

By Agnes Susanne Schulz, Frobenius Institute, Frankfurt

PREFACE

The Frobenius Expedition to North-Western Australia, March–December, 1938, made a survey of a number of the picture caves and rock-shelters of the Kimberley tribes. The World War and post-war conditions have so far prevented publication, so that the account given here is the first to be presented.

The extensive paintings found in rock galleries of the Kimberleys form a class of their own among the widely diffused drawings and paintings of the Australian aborigines. Professor Elkin, who in 1928 investigated some of these galleries, was the first to realize their significance.[1] The very first discovery of representations of the human-shaped but mouthless mythic being Wond'ina was made by Sir George Grey over a century ago.[2] About 1900 Mr. Fred. Brockman travelled the Kimberleys and took photographs of whatever Wond'ina paintings he came across; they were published by F. M. House.[3] In the Northern Territory, D. S. Davidson found rock paintings to a certain extent related to the Wond'ina paintings; in his comprehensive book on Australian aboriginal art he reproduces also some of Brockman's and Elkin's photographs.[4] Grey's much-discussed reproductions can now be compared with the recovered originals.[5] Mr. Coate's researches have widened and deepened what had already been established in substance by Professor Elkin.

A different type of representations of human figures occurs in Central and Northern Kimberley. These representations, the provenence and significance of which are as yet unestablished, have rarely been met with by observers. While the report of the discoverer, J. Bradshaw,[6] dates back to 1892, the first scientific account of the subject was given by C. P. Mountford in 1937.[7,8]

Jointly with my colleague Gerda Kleist, I was entrusted with the copying of the paintings. I am here giving a typological view of the representations recorded. From our headquarters at Munja and Sale River Station we visited the Walcott Inlet district; from the Kunmunja Mission and the little ground-nut farm at Mary Springs, we visited the region further north. Apart from the paintings inspected by ourselves, I am reproducing, from photographs, sketches, and notes, paintings found by Dr. Petri and D. C. Fox on minor excursions and on their overland journey to the Drysdale Mission. Dr. Petri was kind enough to put at my disposal his complete collection of interpretations and myths relative to the picture galleries.

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1. A. P. Elkin, Rock-Paintings of North-West Australia, Oceania, Vol. I., No. 3, 1930.

2. George Grey, Journal of Two Expeditions of Discovery in North-West and West Australia, London, 1841.

3. Fred. S. Brockman, Report on Exploration of North-West Kimberley. Appendix by Dr. F. M. House, Perth, 1902.

4. Daniel Sutherland Davidson, Aboriginal Australian and Tasmanian Rock-Carvings and Paintings, Philadelphia, 1936.

5. A. P. Elkin, Grey's Northern Kimberley Cave-Paintings Refound, Oceania, Vol. XIX., No. 1, 1948.

6. J. Bradshaw, Notes on a Recent Trip to Prince Regent's River, Proceedings of the Geographical Society of Australasia, Victorian Branch, Vol. IX., Part II.

7. T. Worsnop, The Prehistoric Arts of the Aboriginals of Australia. Report of the Sixth Meeting of the Australian Society for the Advancement of Science, Brisbane, 1895.

8. C. P. Mountford, Examples of Aboriginal Art from Napier, Broome Bay and Parry Harbor, North-Western Australia, Journal of the Royal Society of South Australia, Vol. LXI.

Introduction

To understand the Wond'ina paintings a brief summary of their underlying ideas seems to be indispensable.

In primeval times, the Wond'inas, conceived as mythic beings and totemic heroes, wandered on the earth. They made the landscape in its present form. The myths report, for instance, how a hill arose where a Wond'ina had come to rest; how a creek formed on his track; how a mountain grew up from the axe he had made and left behind. The Wond'inas also made, and taught the aborigines how to use, their weapons and tools. They instituted circumcision, cicatrices, all the rites and usages; they made the laws to which man has to conform. On the completion of their earthly activities the Wond'inas went partly down into the earth, partly up to heaven. On earth the spot is mostly indicated by some never-drying waterhole where Wond'ina survives, generally in the shape of the rainbow serpent Ungud. From him comes the rain on which the preservation and renewal of all life depend. In these Ungud places the aborigines find the spirit children, mythic impersonations of the all-essential substance, man's vital power but for which no children are born. Among the primeval laws is the injunction to keep the paintings in the rock-shelters fresh. The thriving of plants and animals, the harmony of all nature, and accordingly the well-being of all men depend on the observation of such laws. The paintings are restored before the beginning of the rainy season; if they were neglected, no rain would fall.

The name Ungud, prominent in the traditions, is less often heard in connexion with the rock paintings. At first the difference between Ungud and Wond'ina seemed hard to understand; for on inquiry the aborigines mostly said the two were the same. Sometimes Ungud was believed the more powerful of the two. In a creation myth of the Ungarinyin it is Ungud who, rising out of the sea, bids the land emerge from out the water. According to one version the Wond'inas spring from his eggs.

Dr. Petri, in the course of his research, arrived at the same conclusion as Professor Elkin; Ungud is the rainbow serpent; the portrait of it too occurs in the paintings; all anthropomorphous embodiments are called Wond'inas. According to their totemic significance they can assume and reassume animal shape. Those who transform into cosmic phenomena do so at the end of their earthly career.

The Wond-ina portraits, in the interpretation of the Ungarinyin, bring out the idea that their bodies are partly filled with blood, partly with water. The blood which makes man and animal strong is rendered by the red ochre bow, the water by the white colour of the face. That way the Wond'inas generate the rain to which nature's fertility is due.

Translating into conceptions familiar to us, we may conceive Ungud and Wond'ina as incarnations of the creative powers in nature and in man. They are the mysterious sources of all life, also spiritual life. Psychically superior men, such as the medicine-man, or artistically superior, such as the poet of corroboree or the composer of a new dance, stand in especially close relations to the Ungud beings.

The renewal of the rock paintings at the end of the dry season ensures rain; disregard of this primeval law would be followed by drought. A procedure of this kind would have been interpreted by an older school of anthropologists as " rain magic ". In the light of aboriginal mythology it is obvious that the preservation of the rock paintings constitutes a significant cult ceremony. At the root of it is a conception concerning the nature and function of images which seems to be common to the majority of ancient cultures and, among many peoples, has survived to the present day. To us this conception is difficult to understand; in fact, no adequate explanation in terms of modern thinking has so far been offered. The portrait is regarded as a living thing and is treated as such. When the shadow on the rock wall fades away, the Wond'ina being vanishes, and thus end rain and fertility.

The visible image is to be preserved as some sort of obligation towards the spiritual being represented. That seems to me an excellent illustration of the religious fact that the supernatural powers need corresponding activity on the part of the faithful if they are to develop and become manifest and beneficial. It is ultimately the significance of all religious practice that, to prepare for the experience of the divine, man has to do something.

Description of the Picture Galleries

The galleries are here grouped according to their principal representations.[1] The majority of these, as far as our finds are

1. The arrangement of the galleries according to their principal pictures with subsequent description of secondary figures was suggested by the large paintings. I retained this scheme for the sake of lucidity although the much-intertwined representations of so many minor motifs did not as readily fit in. I hope, in some doubtful cases, my distinction of principal and secondary cases will not be entirely disproved by later more comprehensive interpretation.

concerned, are portraits of Wond'ina in quasi-human shape. This characteristic appearance he left behind, according to the myth, as his shadow on the rock. " Shadow " in Australian language means " image "; on the other hand, the " shadow soul " is part of man, namely his outward form.

In six of our galleries a lying anthropomorphous Wond'ina dominates the paintings by his size. At three places—in Korályi, Ai-ángari, and Wólang-Kolong his body is covered with Wond'ina heads. This type of representation is not to my knowledge among the material so far at hand.

Among the remaining three large lying Wond'inas is the known one of Modum with two little Wond'inas on his upper part. To him we associate two variations of the type " with two sons ", in the Frobenius gallery at Bínd'ibi and in Malán A. We also came across erect Wond'inas in over life-size. They are, each time in like manner, painted on the ceilings of the galleries near the natural tunnel by which each of these three rocks is pierced. Another common feature is the old frame of their ochre bows. In the exceeding rich and interesting rock-shelter of Malán an upright Wond'ina is superior in length to a lying one so that, in default of a pertinent myth, it is questionable which of the two is the main figure. An erect figure among few other paintings dominates the rock-shelter of Yangálu. The upright figure of Wund'udu in the so named rock-shelter is accompanied only by two Wond'inas in half length.

Less often we found the principal figure represented only by Wond'ina's upper half. The well-known portrait of the Wond'ina Nyandurgaiali in Kálingi is so placed as if he were emerging from out the earth, his legs and also his hairbelt being omitted. (Apart from this figure, the Kálingi shelter has its " big boss " in the shape of a serpent and is here accordingly grouped.) The peculiar representation—so far unique in the Kimberleys—of the Wond'ina Káluru has been published by Professor Elkin.[1] In the Brockman rock-shelter at Bind'ibi, Káluru in half-length stands upright on the wall, again rising from the lower edge of the rock, three large prongs on his head and a mighty lengthened thumb being his distinctive marks. Four close-standing upright half-figures are the manifestation of the Dingo-Wond'ina Am-ángura whose shelter is known under the same name.

Wond'ina heads as leading motif are so arranged in a rock-shelter near Mount Hann that larger heads are horizontal and smaller ones vertical. This recalls the large lying Wond'ina

1. See p. 7 (note 1).

figures whose bodies are covered with heads. As in the Mount Hann shelter the heads are arrayed on very slender rocky steps, it can be supposed that the representation has been so curtailed for lack of space. Special natural conditions make it obvious why here, in spite of so little space, paintings were placed.

In Bradwodíngari a single Wond'ina predominates by striking detail over the rest of the paintings; it is the namegiving motif of the gallery: Brad, the rising sun. The Wurrimodingari shelter, with a few large Wond'ina heads over kangaroos and bush fruits, has been described by Professor Elkin. A small rock painting near Maliba II. is merely an arrangement of Wond'ina heads.

Four of our galleries are marked by images of large serpents. In Kálingi the great Ungud serpent, coming out of the earth, stands bolt upright on the rock. In Monyol it is winding up on a rock shelf. In Maliba I. a group of large serpents seems to be emerging from out the rock. In Ma: onginga the serpent, less conspicuous for a principal figure, was interpreted by the aborigines as representing Ungud.

Myths of animal-shaped Wond'inas too are illustrated in rock paintings. In the shelter of Jándara Wond'ina appears as a big crocodile with features to some extent assimilated to the Wond'ina face. The Frilled Lizard-Wond'inas exhibit preponderantly features characteristic of the tégulan pictures. The distinctive mark is anthropomorphous shoulders and arms instead of forelegs. Most remarkable is the figuring of the Ant-Wond'ina. Only his head is represented by a pair of large eyes with two upward lines from which dotted rows issue horizontally and, below the eyes, radially. An ochre bow may have been painted around previously; remains of colour roughly forming a semicircle are faintly visible under a layer of blown white (Fig. 1).

The galleries on the upper King Edward River are dominated by images of local totems: Large eagle-hawks in one and frilled lizards and yams in the other gallery.

Interpretation of individual paintings was partly given on the spot by the aborigines guiding or attending us through the bush. Further information was obtained in camp by Petri and Fox showing sketches of paintings to members of the clan who " owned " the gallery in question. Such competent people were often not available. Knowledge and reliability of the guides and attendants differed greatly. We have throughout refrained from attempting interpretation on our own account.

Coming from the Ungarinyin—or rather the D'erag, their eastern division in the Mount Hann district—Petri and Fox got first to the Roe River Unambal and, after reaching their destination on the north coast, to the Gwi:ni. No large picture galleries were found with either of these tribes. To them Wond'ina is only an individual mythic figure, namely Káluru. In the traditions other mythic personages are prominent. They are represented, not in rock paintings, but in sacred dances.

Our photographs taken in the galleries already examined and discussed by Professor Elkin are not here reproduced. Some particulars will be mentioned for comparison later.

Our attempt at classification reveals in the vast area of the Ungarinyin an utter muddle of types. The fact that motifs obviously alike have been scattered so widely is one more symptom of those aboriginal migrations which make a clear-cut distribution of culture elements in Australia a rarity. Professor Elkin, in his last paper, holds the view that newly-collected myths will prove the interconnexion of a number of picture galleries.

At the very end of our expedition we came across some examples totally different from the Wond'ina paintings. The figures in question are smaller, of human shape, not white-grounded, monochrome in red ochre, sometimes with a light contour. There is no room for them in present-day aboriginal culture. Felt to be foreign and strange, they are given little attention by the aborigines who interpret them all and sundry as *d'imi,* bush spirits. So far only Bradshaw's early report and Mountford's paper had been published on this subject. Mr. Coate, on his successful excursions, also came across the Prince Edward River paintings supposed to have been rendered by Bradshaw inaccurately and other paintings in the same style. His discoveries will, it can be hoped, throw more light on the provenance and significance of these peculiar and un-Australian paintings. Our own few finds can only be helpful in posing the problem. They have at any rate once more confirmed the existence of such paintings which had sometimes been questioned.

According to a letter from Mr. Charles P. Mountford, there are paintings of this kind also in the Northern Territory. Again the aborigines do not know about these figures, simply calling them *mimi* which again means bush spirits.

WOND'INA PAINTINGS IN CENTRAL KIMBERLEY

Lying Wond'inas Whose Bodies are Covered With Wond'ina Heads

Korályi

Situation.

In Korályi is the largest and most beautiful figure belonging in this group, the Wond'ina Warkálimara[1] Yáobuda. Korályi is one of a number of unaccounted rock-shelter names. It is situated about 8 miles east of the Calder River. The gallery is hollowed out on the west side of the great sandstone rock estimated by D. C. Fox to be 200 m. long, 80 m. wide, and 15 m. high. Rising over the surrounding country it offers a wide view from its large plateau.

Stone arrangements.

There are set up two menhir-like and three dolmen-like stones (Figs. 2 and 3). The two menhirs are arranged about 35 m. from one another in a line pointing east to the 1½ km. distant waterhole. Fox noted the fact without stating his opinion as to whether it was a mere coincidence. The smaller menhir and two of the dolmens stand on top of the picture gallery. The third dolmen, about 50 m. further north, is called " Wond'ina's kidney fat ".

Principal painting.

Inside the gallery, the smooth wall bearing the chief paintings recedes farthest under the heavily projecting roof which rises in irregular gradations towards the front. The fact that Wond'ina's portrait is screened by some part of the rock is a characteristic feature of the picture galleries. The large lying Wond'ina, 5.90 m. long, is in good condition. His large head is adorned with four cockatoo feathers and enclosed with a lightning sign (Pl. 1*a*). The four-fingered hands on short arms are painted black and so are the seven-toed feet. The thorn Wond'ina ran into his foot is here to be seen. The black colour, especially in the feet, has a bluish effect due to the admixture of white and probably enhanced by the red contour[2]. Little is seen

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1. Warkáli wattle (kind of acacia).

2. This observation puzzled us at the time in connexion with the problematic blue " haloes " in four Wond'ina half-length figures reproduced by Grey. The problem has since been solved by Coate finding the blue material used, glauconite.

of the delineation of the body; an older contour of its upper part is unrestored. The body surface is nearly filled up with 22 Wond'ina heads. Of these seventeen are repainted, five seem to be somewhat older; they are at least more sketchily done.

Secondary figures.

The tiny heads upon the feet have become indistinct. Such entries do not belong to those motifs which it is an obligation to restore, but are made only once by a man who has found a spirit child. An animal's head near the lower foot is explained as that of an eel; a long white something above as yam; a figure further to the right as a serpent-like monster used by Wond'ina as food. Six white double circles above the feet of the large lying Wond'ina may represent the same motif as the halved white ovals interpreted in the Frobenius gallery as fog clouds (Cf. Fig. 9*a*). The largest Wond'ina carries a marsupial mouse under his feather dress.

Earlier representations (Pl. 11.) beside the large head are blown over with white beyond recognition. Only an older Wond'ina head below the two upper cockatoo feathers is still sufficiently distinct to allow to recognize a type of face that became obsolete; it was, in fact, never found in repainted, though occasionally in very weather-worn, heads. The encirclement of this head (Fig. 16 *b*) is more clearly perceptible because not, as was the practice in repainting, overlaid with white; it was interpreted as fog clouds. This girdle of curved lines has its analogues in certain obsolete and never-renewed motifs round the heads of upright Wond'inas (Cf. pp. 59-60). The new paintings beside the large head are three Wond'ina heads and three bats hanging as when resting on the trees. A lying figure, cross-lined all over, was interpreted as *mulu-mulu,* a female Wond'ina. Her character was not stated; in general the mulu-mulu are reputed evil (see under Ai-ángari). Nor was any emblem of hers mentioned although a dark rectangle was suspended on her lower hand. This rectangle may be a bark pail, as comparison with the one seen at Ai-ángari seems to suggest, though it is not seen in top view here. Two representations, further up, of the rainbow serpent emerging out of a cloud (Fig. 10) are only partially distinct. There are faint fragments of older versions of the squatting woman motif (Fig. 12*b*): the oldest was of very large size. The peculiar figures right on top (Fig. 4) were explained in detail, as noted in the captions to the reproductions.

To the left of the main group of paintings, the rock wall projects at an angle. A figure, 94 cm. high, with raised arms is drawn there in broad red lines. Two natural holes in the rock wall are incorporated in the picture, representing eyes. Long bristling hair is edged with a contour from which denser little strokes are sticking out. This is an unusually large-sized representation of a kind of being called by the aborigines *devil-devil* and feared by them especially in the dark. The rock here is very uneven. A red-contoured animal figure is set above yellow leaf-like forms (Fig. 5). Some silhouetted hands, owing to the bright reddish-yellow patina of the rock, stand out very colourfully against their blown white foil. Some of the weathered fragments of paintings are supposed to represent tuberous fruits. A red-edged white emu footprint recalls frequent engravings of the same motif which is rare among paintings.

Myth.

The myth relating to this picture gallery was told by old Bronco who at the time of our expedition lived at Munja Station.

Káluru came from the north, accompanied by a host of little Wond'inas. Once seeing a stone, he thought: That is a good stone for an axe; let us make an axe. Together with his little attendants he made an axe. For days they struck it into shape, for days they rubbed it smooth and polished it. Inadvertently the stone axe began to grow, it grew and grew into a mountain, part of the Edkin Range. The big and the little Wond'inas went on, by day walking south, by night sleeping in the rocks. Thus they arrived at the Calder River Crossing. When the big Wond'ina was crossing the river, he ran a strong sharp thorn into his foot; it was very painful. The spot is still called Ungud's Track; a large footprint is said to be visible on the rock. The pain did not abate so that the big Wond'ina lay down and the little ones went to fetch a stick. They took one of those trunks wherein the bees like to build their honeycombs. Leaning on the stick and supported by the little ones the injured Wond'ina went on, turned east and north, and arrived at the tambun Malango. Some of the little attendants ran in advance and quickly prepared for his camp in the Korályi shelter. There they laid down the big Wond'ina; for he was very tired. His stick they leant against the wall, his mug they hung in a crevice. These things are extant. A large nautilus shell is lodged in a crevice, the trunk is leant against the wall in front of the *devil-devil*. They must not be touched.

Of the Wond'ina with the marsupial mouse the story goes that he discovered the animal in the trunk of a tree where he was hiding. He meant to eat it by himself and so tried to conceal it under his feather-dress. But the other Wond'inas got aware of his stratagem; so, after all, he must share his prize.

Old Bronco bears the name Kálingi[1] Warkálimara Yáobuda. He is an impersonation of Káluru, the great Wond'ina of primeval times. He has a sore foot which sometimes deteriorates, though at other times it is less annoying. It will never heal up, for it has been injured in the dream-time, and what happened then will remain for ever.

Situation.

Paintings in many respects similar to those in Korályi were found by Petri and Fox in Ai-ángari in the Mount Hann district on the left bank of the upper King Edward River. The name is a compound of *aia*, a kind of serrated leaves, a favourite emu food, and *ángari*, belonging to. The shelter is situated in a chain of sandstone rocks abruptly rising on table-land.

Principal painting.

The portrait of the large lying Wond'ina is once more found placed on the rearmost part of the wall (Pl. I.*b*). Red ochre is the colour mainly applied, only the thin and firm and remarkably steady contours of the large Wond'ina and all eyes are black. The eyes of the large one are edged with a delicate black line; their inner surface is lighter, owing to the admixture of white, and has a bluish effect (Cf. p. 13, note).[2] Twelve upright Wond'ina heads cover the upper two-thirds of the body. Red strokes on the legs near the knees look like a suspended adornment such as are customarily worn in dancing. The feet are more expressively delineated than those of other lying ones; the twice five toes are elaborately painted at their tips, perhaps an intended representation of the nails. Eight of the upright heads have been freshened up recently. Four smaller ones are of older date and so are the somewhat faded animals, two wallabies and a bird, an ibis. Any body design is absent between the heads, here as well as in Koralyi (Fig. 31*a*).

1. Kalingi, i.e. rain.

2. Two features are typical of the Mount Hann, in deviation from the more southern, paintings: Large close-standing eyes entailed by a more slender nose, and white areas inside the ochre bow which, according to an interpretation given to Petri, represent clouds.

Secondary figures.

About 2 metres from the feet of the lying Wond'ina is the portrait of an upright Wond'ina woman, a mulu-mulu (Fig. 6). In one hand she holds an upwards-running cord, in her other hand a bark pail suspended by a string and seen in top-view as a plane round with a bright nucleus.

Further to the left, where the rock is more projecting, there are two further Wond'ina heads similar to those on the large lying one. Between them a bird is drawn in white contour. Above the outer Wond'ina head is a white spot and a single white oval bow reminiscent of those fog-cloud encirclements no longer in vogue (Cf. p. 52). If indeed the white clouds on the ochre bow are meant to represent clouds, the case would be one of change of form without concomitant change of ideas.

Another analogy to Koralyi is a large shell likewise sticking in the rock and believed to be Wond'ina's mug. We did not find this attribute in any third place.

Myth.

This is the tale of a *mulu-mulu* recorded by Dr. Petri and here condensed.

The *mulu-mulu* went hunting. She captured two boys and took them in her bark-pail to the Ai-ángari waterhole to cook and eat them. But first she dipped for lily roots. In the meantime the children crept out and ran back to their camp, crying loud, for they had already been skinned by her. The *mulu-mulu* pursued them into the camp. The men threw their spears at the Wond'ina woman, but all rebounded from her hardened skin. At last one hit her feet; down she fell dead. Her shadow and the shadow of her pail remained behind on the Ai-angari rocks. Vulnerability at her feet is also mentioned by Professor Elkin.

Wolang-Kolong

Locality.

Wólang-Kolóng is situated high up in the massif Lushington Bluffs, about 14 miles from Sale River Station. The large group of paintings stretches over 7 metres. They are sheltered from rain by far-overhanging rock. Above the Wond'ina portrait the stone is veined with light and dark horizontal streaks.

Principal painting.

Hardly any traces are left of the body of the large lying Wond'ina. A dark streak severs about a quarter of the paintings on the left-hand side from the rest. There I seem to make out the contours of two feet, although the photograph does not permit to state this with certainty.

The head is painted on the rock into a deepening which is perfectly even and rectangular as if so hewn out. Beside the large head, on his breast, are four upright small Wond'ina heads. Higher up, on a slightly projecting piece of rock, the large Wond'ina's arm rests with his five-fingered hand. Beside it and above the lying head there projects a boulder, again smooth and rectangular as if so hewn. On it is painted part of a serpent with raised head and, near by, an oval, a serpent's egg. Under the hand of the large Wond'ina is seen his hair-belt set exactly along the edge of the regular deepening mentioned. To the left, the surface is predominantly covered with Wond'ina heads part of which are too weather-worn to be recognized in detail. About the centre is drawn a Wond'ina's upper half with one arm, his head being enclosed by older, hardly perceptible curved lines. These never-repainted motifs have already been mentioned in connexion with an older drawing in Koralyi (See p. 17 and, for general observations, p. 53). On the lower left, near the dark streak, is seen a Wond'ina head and, on top of it, another unrestored painting which was positively designated " rainbow serpents in a cloud ".

Secondary figures.

On the upper left is a much-faded Wond'ina head with apparently the old type of face, enclosed with a new threefold bow. Above it rises the head of a long-necked tortoise, painted conspicuously on the frontal face of a step-like projection, while the neck is set on the bottom of it.

Two wallabies look almost like one two-headed animal owing to the relative position of their heads and forelegs. In fact there are two figures drawn independently of which, to judge from the photograph, the right one is the older. The dot-filled circles, a conventional representation of bush plants, were stated to be small yams. The ovals aligned on the rocky steps to the left (Fig. 20*b*) were interpreted as *lámbara*, a white worm, about 15 cm. long, also known as witchetty grub, which is much appreciated by the aborigines for its sweet taste.

On the leftmost side of the large group of paintings, beside the bow round the head of the long-necked tortoise, are the faint fragments of a head encircled with rays, an old representation of the sun. Such is also the signification of a figure to the right of the principal group (Fig. 7).

The little rod-shaped figures on top of the Wond'ina paintings remain to be mentioned. Sketches of two such squatting figures are here reproduced in juxtaposition with analogues from the Frobenius shelter (Figs. 12*a* and *c*).

Large Lying With Two Wond'ina Figures

Modum

The Módum gallery with the well-preserved Wond'ina was made known under the name Belguldo by Professor Elkin. His descriptions and photographs need not here be repeated. Further investigation may perhaps bring to light some myth of a Wond'ina with two sons, " son " to be taken as a kinship, and not a family, term; for that combination recurs in two other groups of paintings. However, the twoness may have been suggested as well, in each of the three rock-shelters, by the available space. In Modum the legs of the upper little Wond'ina are unrestored; their traces are discernible below the large one's hair-belt under more densely blown white. The lower little one is painted entirely afresh, body and legs being so curtailed as to fit in as much space as in the upper portrait is occupied by the upper part of the body alone. That in the process the arms have come to reach down to the feet indicates that originally the representation was of larger size correspondingly to the upper one. Apparently it seemed awkward to the artist doing the repainting that the legs of the little Wond'ina should be seen below the hair-belt of the larger, and he may have tried out two divergent alterations: One, by retaining only the upper part of the body, the other, by curtailing both body and legs excessively. It would be no use to ask the aborigines about the true significance. So intensely are they directed on the objective side of their ritual performances that they are not conscious, as we understand the term, of their own activity or capable of reasoning about it.

On our way to the Brockman gallery, which had already been described by Professor Elkin, our aboriginal guide took us, not immediately to our destination, but to another picture gallery at the end of the same Bind'ibi valley. There we found the most

weather-worn paintings we ever came across, which had obviously been unrestored for years. It must be assumed that the horde of this rock-shelter has died out.

On the proposal of our Australian friend Patrick Pentony we named the locality Frobenius shelter.

The Frobenius Shelter

Locality.

The Bínd'ibi valley is enclosed on both sides by steep rock walls rising 80-100 m.; it opens on a vast plateau and, at the top, ends in stone deposits. Above such a stony declivity is situated the Frobenius shelter in a huge rock. A little above the ground, the wall offers a long smooth surface, only one uneven spot interrupting the succession of paintings stretching over some 12 metres. The almost horizontal roof of the shelter projects far over.

Principal painting.

At 6 m., the lying Wond'ina surpasses in length the one of Modum. The painting is in bad condition, the white ground peeling off. Water seems to have trickled down from above the head, a dark streak running over it perpendicularly, blotting out the black ovals of the eyes and leaving only the lower edges of the eye-lashes. The eyes and nose are not of adequate size to the wide facial area of the huge head, but are set somewhat obliquely in the lower half of the white round. On top of the ochre bow which is marked with red little hair strokes, three cockatoo feathers are bristling up. This feather adornement, enclosed with red circlets and, sideways, with radially arranged little strokes, is framed by the lightning sign, an unfurcated wide-spanned bow. The two arms of the large lying Wond'ina are carried out; we repeatedly found the lower arm omitted when the Wond'ina was too near the edge of the painted area. The right arm is close to the body, the left one slightly downwards bent as if to embrace the little Wond'ina figure on his left breast. The second little Wond'ina stands below the large one's head. The only clearly perceptible part of this figure is an arm, while the rest of the body is vanishing under the white paint and the little strokes inside the lightning bow. The is no vestige of feet, though I seem to make out the contour of a leg.

Secondary figures.

In a niche-like deepening of the rock, on the left of the large central group, stands an upright Wond'ina figure with long bristling hair strokes, throughout painted in yellowish-brown ochre. Next follow a large kangaroo, 1.30 m. to the tip of the tail, and a long-necked tortoise, 70 cm. long (Pl. IV.*c*). Pictures we found of the latter animal were repeatedly more or less weather-worn and in no case restored (Fig. 25*b*). The leftmost item is a small figure, 26 cm. long, in red contour on white ground, with feet beyond proportion, and with stretched-up arms. This figure is remarkable because an identical design, likewise on the extreme left, is seen on top of the paintings in Maliba I. (Pl. XIX.*a*). Unfortunately no interpretation is available as to the significance of such features in either of the two galleries.

Passing over to the right-hand side, we find beside the head of the large lying Wond'ina a well-preserved little group with a motif not frequently seen in such distinctness: The rainbow serpent emerging from out the clouds (Fig. 9*a*). Below it stands a little Wond'ina figure; on the right, a porcupine and a crocodile. A second porcupine to the left is half covered by the lightning sign of the large lying Wond'ina. An analogous motif to the representation of the rainbow serpent occurs in the Brockman gallery (Fig. 9*b*).

Further to the right the paintings are becoming more and more indiscernible. The only thing that can be made out with certainty is that there is no vestige of a white ground and the figures are not contoured, but their areas painted. Of some lying creature in yellow the best perceptible parts are the feet and thin legs. The upper part of the body looks like a bale; where one should expect to find the head there is a bundle of long strokes like a tuft of hair. That is a feature reminiscent of the engravings near Port Hedland, far south on the west coast of Australia. There are, furthermore, peculiar white-coloured forms of doubtful significance, possibly representing insects. This design recurs twice high up on the rock wall above the legs of the large Wond'ina (Fig. 11). Near by are a great many small paintings, similar in type to the squatting rod-shaped figure (Fig. 12*a*).

Myth

The paintings are thoroughly weather-worn. It is pretty safe to assume that the local myths perished with the people of their horde. Thus mythical tradition is borne out by events: A manifestation of Wond'ina is vanishing.

While it was our good fortune to come across the Frobenius shelter, we were handicapped at Bind'ibi by a number of circumstances. First of all, the location of our camp proved a failure; in the first days we had to spend more than two hours a day walking to and fro. When asked for help through an aboriginal messenger, Petri and Fox, who were working in the vicinity, came down with some pack animals to resettle us. In these spacious galleries, so rich in interesting features, we felt deep regret that we could not give as much time to everything as we thought fit, for we depended for our movements on the mounts and pack animals lent us at Munja. On account of farm requirements the time granted us for the visit to Bind'ibi was scarce even for the one Brockman gallery about which we knew from Elkin's paper. When our programme was unexpectedly enlarged by the Frobenius shelter, we could not do our task so well as we wished to. Moreover, a difficulty commonly facing the copyist of rock paintings was even more pronounced in the Frobenius shelter. Old weather-worn paintings are often of particular interest. Now the copying of such paintings, laborious in itself, is infinitely more so if one is to render ambiguous features accurately while not anticipating interpretation. Still the result of one's sustained efforts, compared with the original fragments, is only too often unsatisfactory.

Malan A

Situation.

Malán is situated at a considerable distance north of the Walcott Inlet district to which the above-mentioned two galleries belong, beyond the Glenelg river. We got there from Wurewuri, covering the 12 miles' distance to the south in a two days' ride. In a large rock spacious shelters have formed on three sides and a low passage near the centre. From the hill topped by this rock there is a wide view over the monotonous bush scenery around.

Principal painting.

On the right side of the rock is a natural niche in front of which a small platform rises about 3 m. above the ground. A large lying Wond'ina fills this niche completely (Pl. VI., right). The two "sons"—the word again taken as denoting kinship, and not family, relationship—are not painted, as in Modum, on the large Wond'ina, but beside him in two small adjacent niches. It is delightful to observe how such natural features are incorporated in the composition. The large Wond'ina is equipped with an unusual head-dress which leaves no room for the common lightning

sign. Here a red-coloured one is put round his arm serpentine fashion. The middle cockatoo feather rises high above the head, bordered on both sides by hatched elongate forms (Fig. 13). The red lines inside the large Wond'ina's body deviate from the common longitudinal pattern in that sets of parallel lines are given curved or angular shape.

Secondary figures.

The various animals are distributed over the bulges and steps of the overhanging roof to which also the large Wond'ina's arm extends (Fig. 14). The dingo and the native companion are the largest groups. The ovals beside the latter were interpreted as its eggs. Five bats are depicted head downwards in hanging position, the customary way of representing these animals. The forms marked with little strokes on one side are tuberous fruits, supposedly *tergun*, a pungent kind of yam, which is prepared by watering, beating, and roasting. Beside the dingo are seen two small birds which according to the aborigines "live near the water". Which of the many species of Australian aquatic birds that statement implies, is hard to say.

Large Erect Wond'ina Figures

Malan B

Location.

Under the designation Malán B are comprised groups of paintings found in the spacious galleries of the huge Malan rock. A passage about its centre has already been mentioned. Near the passage is a far projecting piece of rock with a perfectly smooth lower part. Further to the left, the south-west corner is on either side overhung by high-rising, far-projecting rock.

Principal painting.

In the first-mentioned place, on the ceiling which is inclined slightly backwards, stands the upright Wond'ina figure, 3·50 m. high (Pl. VI., left). The head is 97 cm. wide at eye level; the long-lashed, rounded eyes resemble those of an owl; the long nose is ornamented with several rows of white dots (Fig. 15). These facial features suggest that the being before us is the night bird Wond'ina. There are round the ochre bow extremely faint traces of long rounded forms similar to those beside the cockatoo feather of the large lying Wond'ina at Malan A. The body ornamentation with curved and undulating lines is unique among our finds. Above the right shoulder are emerging three little half-length Wond'inas.

Secondary figures.

The upright Wond'ina type recurs in the group of paintings found at the south-west corner on the left end of the side of the rock described above. Again it is a roof gently sloping to the rear which, in spite of a good deal of unevenness, bears a number of much-faded paintings. Two upright Wond'ina figures (Pl. VII.) stand close, 1 m. high, rising above the neighbouring figures. Their bodies are patterned with red vertical lines which are denser and more determined than in the smaller, recently repainted one. Both Wond'inas have those close-standing rounded owl-eyes. In the repainting of the smaller figure this feature has been enhanced, very long red eye-lashes being accented by thick black dots. The peculiar head-encirclement has again been omitted in the repainting, but is somewhat more distinct than in B.

Above and to the left are quite indistinct, almost obliterated drawings of birds and stencilled hands between imperciptible fragments. A number of dark broad parallell stripes may represent a group of Ungud serpents, but they are too faint to allow to make out any serpent's heads. To the right follow the fresh picture of a fish and faded circles and ovals, hatched lengthwise or across or filled with dots. Beside these conventional representations of bush fruit there were two forms novel to me: Shaped like boomerangs, half yellow and half red or filled with little red and white dots. They were unhesitatingly described by the aboriginal attendant as sugar-bag, that is, wild honey. Supposedly what they represent is *mai angari*, sacred boards, which are identified with certain foods of which wild honey is among the most important.

It remains to mention some sort of cave on the west side of the rock, dimly lit by a narrow entrance. A very large Wond'ina and some smaller ones can be guessed rather than seen. The drawing of a small kangaroo differs from the common type; it is more animated in the manner of the Kobuda drawings.

I noticed no significant stones or shells, nor did I obtain any myth relating to the Malan shelter. Unfortunately, I was here alone and the settler accompanying me pressed for our departure almost immediately. He had, indeed, much trouble with his mules which tried all the time to run away because of the scanty food at the end of the dry season. For the rest, apart from the Wond'ina paintings, I found here figures of a different kind which claimed the greater part of the little time available.

Yangalu

Locality.

Yangálu is a small picture gallery on the east bank of the Glenelg River, north-west of Malan. It is situated in a detached rock of remarkable shape. The rocky mass, projecting all around, so tapers down as to rest only at five points on the ground, spanning a wide arch over a spacious tunnel in the centre. The name Yangalu means rain cloud. In Modum and in the Brockman gallery at Bínd'ibi we found (Fig. 8) lying in front of the paintings large boulders which were described by the aborigines as rain cloud. Here the whole mass of rock is thus conceived since it is relatively so little attached to the ground.

Stone arrangement.

One small and two large polished oval stones are lying right under the repainted Wond'ina figure.

Principal painting.

Again it is the rocky, here more precipitous, roof which on its lower part bears an upright Wond'ina, 1·77 m. high, the most distinct picture in the gallery. The red cockatoo feathers with black ends are white-dotted; fifteen double rows of white dots are set on the ochre bow, six on the breast-plate. Hair and eyelashes are of regular length and density, ending in black dots. The body is covered with red lines running all through closely parallel. " Him very pretty fellow ", the aboriginal proudly remarked with respect to this figure. The right arm is blurred, and the feet, if represented at all, are in any case beyond recognition.

The upper part including the head—1 m. wide at eye level—of a large Wond'ina above the " pretty fellow " are extremely weathered. Eyes and nose are so indistinct that it is hard to decide whether they are of the rounded owl-like type; but the encirclement of the ochre bow with the repeatedly mentioned oval forms is sufficiently clear to allow cross-stripes and two eyes to be discerned in some of them. Two ochre bows further up the rock are entirely faded. Better perceptible is a threefold red stroke with intermediate white ones, a design which was interpreted as lightning.

Minor figures.

The rest of the Yangalu paintings comprise a Wond'ina head and a Wond'ina half-length, a set of tubers, and a bird. The bird, it was said belongs to Wond'ina and lives near the salt water.

The tubers were styled " chicky burnmouth ", the *Uergun* yam already noticed at Malan, an important food in the Kimberleys.

Myth.

All our aboriginal guide had to say was that the stones were food that belonged to the great " old " Wond'ina with the metre-broad head. No longer did he come up in a cloud to the place, only the younger one did.

Wund'udu-Modíngari

Locality.

Wund'udu-modíngari is a picture gallery on the lower King Edward river, so named after a representation of Wund'udu or Walanganda. The painting is found in a passage which is nearly like a rectangular gateway. In particular the ceiling is smooth and straight except for a slight lateral inclination. On this ceiling stands Wund'udu, thus occupying a similar position as the previously described Wond'ina figures on the Glenelg river which are also placed on a sloping roof. There are also passages in the centre of the rock both in Malan and Yangalu, only these are lower and the paintings are near by, not inside.

Principal painting.

Wund'udu, or Walanganda, exhibits the features commonly found in the Mount Hann district (Pl. X.). The large eyes are close. The nose is a slender stripe, barely thickening at its lowest part and passing above the eyes almost as far as below. There are broad white stripes inside the ochre bow. The old frame of the latter is not restored any more than in the above-mentioned figures (Fig. 16*a*). Here the fresh ochre bow is covered with those white spots described as *ondolon*, that is, fog cloud, a feature frequent in and, as far as our experience goes, confined to the Mount Hann district. If indeed the bow-shaped designs are an older representation of fog clouds, as was stated to us in Koralyi, they may here be replaced by the white spots inside the ochre bow. At its lower part, about the feet, the Wond'ina figure has not been renewed. Here as usual the red colour indicates the older stratum. In the freshening-up, what commonly is red in the Wond'inas has been painted yellow. The dark ochreish-yellow instead of the customary red may be taken as characteristic of the nature of the personage represented. Walanganda indeed is the celestial hero of the Ungarinyin, being visible on the sky as the Milky Way. Such may also be the symbolic meaning of his strikingly bright-white hands.

Secondary figures.

Here the large Wond'ina figure is accompanied only by two similar half-length Wond'inas. In these figures mainly yellow is applied, apart from some black and white. One ochre bow is densely covered with white dots, which are absent in the other.

Myth (from Petri's unprinted manuscript).

Walanganda belongs to the great Wond'ina heroes which are of more than local significance. The whole tribe of the Ungarinyin regards Walanganda as the originator of the initiation ritual. He also introduced hunting as practised by the aborigines to-day. Various mythical versions exist of how Walanganda came to heaven. In two of them his injured leg plays some part. He is said to have incurred it when struggling with another mighty Wond'ina. Lying helpless on the ground he prepared water-lily roots in the ashes of his fire. When the roots were done they burst so vehemently that Walanganda was thrown right into the heaven. There his broken leg turned into a *mai-angari* (sacred board) while the lily roots are visibie as the Magellanic clouds. The other myth relating to his injured leg pictures Walanganda getting fed up with his condition since he cannot hunt kangaroos with one leg. He must ask a Wond'ina to spear a kangaroo for him. Walanganda then, leaving his shadow behind on the rock, went up to heaven by a thin thread. By the same thread he will return to the earth nightly. His heavenly " camp " is said to be in a cave where a second exit " leads to the other side of heaven ". There is a world like ours, only that everything is more beautiful: More water, more shadow, more game, wild honey and yams. There Walanganda indulges in hunting together with the shadows of great Wond'inas. Sometimes, when cooking his hunter's kill, he throws a glowing piece of wood wide into the open, that will then be seen as a shooting star.

With the Unambal, Walanganda (according to Dr. Lommel) is the maker of the heaven and of the animals and plants. He also did the original painting of every one rock painting and inspired it with his power.

Upright Wond'ina Half-Figures

Amángura

Locality.

Amángura is the name of the dingo picture gallery on the Glenelg River after the proper name of the Dingo-Wond'ina. It is situated in the Worora district north of the Sale River. The

location resembles that of the Brockman gallery at Bind'ibi. At the top of the rubble-studded lateral slope of the valley rises a steep rock wall. At its foot opens the gallery.

Principal painting.

Four upright Wond'ina half-figures (Fig. 17), remarkable by thick red dots, are less well preserved than some of the animal pictures. This implies that, when the local totems were restored, the Wond'inas were not.

Secondary figures.

Above the four Wond'inas is seen the drawing of a fish painted over with the same thick dots (Fig. 18*a*). It is a black bream which lives in rivers and stagnant waters. Six dingos, male and female, are painted next to it (Fig. 19*a* and *b*). A flying opossum too is supposed to be here represented (Fig. 46). To me the figure looks so much like some of the pictured birds that I should prefer to interpret it correspondingly.

Wond'ina Heads

Wond'ina heads we found repeatedly as the principal motif in smaller picture galleries. Here and there the peculiar formation of the rock stimulated the imagination of the primary painters so that they even chose places where no larger smooth surfaces were available as a delightful though restricted background.

Kand'álngari-Odin

Locality.

Kand'álngari-ódin is an example of a picture place selected for the reasons just mentioned. The gallery is not far away from the Walanganda up the natural gateway. In the low rock-shelter, inside a long and, on the whole, flat rock, there is space only for a narrow strip of paintings. The place was probably chosen for the peculiar effect of some quartz intrusions in the dark-brown patinated sandstone of the far overhanging roof. The roof lowers to the back in irregular stages, the last two steps being part of the rear wall. These narrow strips bear a succession of Wond'ina heads which stand out effectively against the dark stone with its light veins. One of the latter looks like the forked lightning sign (Pl. XXVIII.).

Principal painting.

Over 30 Wond'ina heads, except for four lying ones all in upright position, are aligned along narrow, smooth strips of the wall, several metres long. Two of the heads, which are considerably

larger, are similarly contrasted against the multitude of smaller heads as, in the previously mentioned group, the large lying figures by the Wond'ina heads covering them.

Secondary figures.

Lámbaras, the sweet-tasting larvas, are here frequently drawn, part of them inside the Wond'ina heads. Small crocodiles or rather, according to aboriginal interpretation, alligators, are drawn with animation, part of them horizontally on the rock.

Máliba II.

Locality.

Máliba II., a small picture gallery about 150 m. north-east of Máliba I., on the east side of the Calder river, was a chance discovery of our colleague Lommel when strolling about. The rock has almost a mushroom shape. In the centre, under the upper hood, the stone bends gradually backwards. On the innermost vault are painted five Wond'ina heads. Underneath, the rock forms a fairly rectangular projection which, by its even and smooth upper surface and by the rock wall roughly dividing into three columns, is suggestive of a table.

Stone arrangement.

About 23 m. in front of the rock are two concentric circles of boulders disposed at small variant intervals. The outer circle is about 6, the inner 2·50 m. in diameter.

Principal painting.

The uppermost Wond'ina is the largest. His broad ochre bow with many double rows of white dots nearly closes at its lower ends. Upon the forehead a foot is drawn in outline. A design occurring beside as well as above the head, which is fairly perceptible although partly blown over with white, consists in white and red curved lines with a white oval rising on top of them. This recalls the representation of the snake-like tortoise in Wolang-Kolong. Three Wond'ina heads underneath are also restored on a thick bright-white ground. An older head on the upper right got a share of white in the blowing process.

Secondary figures.

Various designs presumably representing bush fruit are surrounding the Wond'ina heads. The half-hidden something on the upper left seems to be branching out in regular semi-circular shape. The question is whether it is of the same type as those unplaced designs which, wherever found, belonged to the older strata of paintings (Cf. Figs. 42; 43*a*, *b*).

Myth.

We were greatly surprised when the attending Ungarinyin qualified this painting as "rubbish": It was done by blackfellows; it was not due to Wond'ina. We could not get anything more out of him. Possibly his remark sprang from disappointment, since the place had been found by Lommel without his assistance. He was a vivacious young man who seemed to be attached to the spirit world of the traditions by imagination rather than esoteric knowledge. He dramatically described a struggle with Wond'ina in which he was involved owing to some blunder on our part. It was not clear whether he really believed in that experience or was simply putting on airs. Regarding the stone circle, the aboriginal said Wond'ina had been sitting there and ordained the pictures in Maliba I. to be painted.

Bradwodíngari

Situation.

Bradwodíngari is situated in the tambun Nalár on the upper King Edward river. In front of the picture rock there is first a fairly level stretch of ground; then a declivity leads down to the creek, a distance of about 200 m.

Principal painting.

Brad, the Wond'ina of the rising sun, is represented only by his head. In his capacity as a celestial hero he is painted in yellow ochre like Walanganda. The ochre bow made up of several stripes almost closes at its lower part, the nose reaching into the gap between its two ends.[1] On their upper side the two lines marking the nose meet the ochre bow and are continued in an oval which may perhaps represent a cockatoo feather. The eye-lashes are especially long and dense. Above all, the long straight hairs, alternately light and dark, resemble rays.

Secondary figures.

On the right and left are pictures of kangaroos facing Brad. Above the largest and best-preserved one is seen a series of kangaroo footprints. These are especially frequent at Bradwodíngari; they are mostly rather weathered. Wond'ina heads as well as half-lengths and a full-length figure of a small lying

1. According to an oral communication from Dr. Petri, the much-lowered oval of the nose once gave rise to the theory that Brad was represented with a mouth. This seems to me to be disproved by comparison with the older type of the Wond'ina face (see Figs. 9*b*, 16*b*; cf. pp. 44 and 52-3).

Wond'ina are partly very faint, partly in the same state of preservation as the head of Brad. There are also older drawings of bush fruits, round forms with little strokes at their lower part presumably representing root fibres.

Myth.

The aborigines attending Petri and Fox stated that all members of the Brad clan had passed away, so there was no one left to tell the myths of Brad.

Ungud Serpents

Kálingi-Odin

Locality.

Kálingi-odin, on the Backten Creek, about 80 miles north of Munja, we were warned, was difficult to reach. In fact, after passing the Calder Junction we had for hours to struggle across impassable rubble and underwood. Once arrived, we found ourselves in an unusually nice and comfortable camping place. A large and deep waterhole lies about 8 m. in front of the rock wall. The shore here is even and flat. The water shines with a bright turquoise green between the reddish cliffs and the darker leaves and bushes. There the black bream lives, a fresh-water fish and a favourite food of both whites and aborigines. The rocks rise high up, only at the top slightly bending forward to form something of a roof; there can be no speaking of a shelter. The huge wall provides a throughout unlimited background to the paintings. They thus appear smaller than the groups of paintings enclosed in the natural setting of a true gallery. Accordingly our copies although limited to a third of the original size approximated the immediate impression more than we expected, which reconciled us to the fact that we had to leave behind the big paper roll in order to reduce our luggage weight for the difficult way.

Stone arrangement.

In front of the principal paintings is set up a little stone monument, probably the centre of an ancient fertility cult (Pl. XIV.).

Principal painting.

The middle of the chief group of paintings is occupied by the picture of a large serpent, the Ungud Kálingi. He seems to be emerging from out the earth and ascending the rock (Pl. XV*a*). Also an erect Wond'ina in half length, on the right of the Ungud.

reaches nearly down to the ground. His name is Nyandugadali, "Hair-of-the-armpit". We can compare our photograph of 1938 with one taken by Brockman in 1901 (Pl. XVI.). The peculiar animation of this Wond'ina with his somewhat oblique head, slightly bent arms, and spread fingers has been maintained in all renovations during 37 years. Some minor figures have been added to the Wond'ina portrait since Brockman's visit.

To the principal painting may also belong the two serpents to the left of the upright Ungud, nearly of his size, lying upwards upon one another (Pl. XVI.). They are Ungud's wives, surrounded by grotesque smaller figures. The upper one's name is Waiwangari, the lower one's Lirindindi. They are Unambal, whereas Kalingi is Ungarinyin. The small figures (Fig. 51) are spirits brought in by the serpent wives from the country of the Unambal.

Secondary figures.

The Wond'ina heads and the representations of yams and other tubers interspersed between the Ungud and his serpent wives have been increased in number since Brockman's photographs were taken (Pll. XXIV. and XV*b.* right). At a few metres to the right of the main pictures is painted a delightful group. Nine yam tubers are lined up in close succession. Rising slantingly they tend to the horizontal half-length portrait of Nurind'ángo ("Scratching-the-ground"). The little Wond'ina above the row of yams is his son Lilingo ("Breathing-in-hissingly") (Pl. XVII.). The three lower Wond'ina heads with lightning signs on top of the ochre bows are likewise designated: To the left, Mangaréen ("Spit-out-by-Ungud"); on top, of smaller size, Dangarun ("Lily"); to the right, Kadurluno ("Hungry-belly"). Oval and round bush fruits fill up the intervals. From behind Wond'ina's little son Lilingo is emerging an older red-painted figure whose raised arms and bristling hair are bordered with light contours—an example of the painting technique without white ground which must have preceded the current white-grounding. Two serpents whose broad bodies are tapering towards their heads are rising slantingly face to face above the lying Nurind'ángo. On either head are seen four crosswise sticking-out protuberances. This peculiar accessary is unique among our finds. According to D. C. Fox's notes, the white-headed and white-tongued yellow serpent on the left-hand side was described as Nalata, an equivalent name to Ungud; the red serpent on the

right was a bat; a small yellow serpent by the side of Nalata was Kulaibada, the seed of Kanmángu, the kind of yam here represented; the seed was brought in by the rock-pigeon whose picture was seen between the small and the large yellow serpents. The design is in fact only dimly visible near the edge of the white ground. Round the small two-eyed head, strokes are sticking out like those round the tips of the yam tubers. To the pigeon is ascribed the thriving of the Kanmángu yam. I would venture the hypothesis that different and perhaps older mythical ideas were originally underlying these paintings. The rock pigeon occurs in a myth concerning the origin of the human limbs and senses. Kaluru (Kaļingi) chased the rock-pigeon Banbarnga. She fled, and in her anxiety made a great noise. Frightened at the noise, Kaluru opened his eyes; up to this moment he had been living in darkness. Then came Wandi, a big serpent, and opened the mouth of man. (From Petri's unpublished manuscript.)

On the large rock wall of Kálingi-odin, older paintings without a white ground are preserved in several places independently of the above-described paintings. Large serpents and yams prevail also in these older representations which are much obliterated and for the most part incomplete. Certain of the serpents, it was stated, were severely injured in a huge conflagration. Some peculiar figures such as recurred nowhere else were described as *guruno,* that is, " the burned people ". They were shy, harmless creatures who would " go down inside " on any one's approach. The interpretations of the Kalingi paintings as well as the following myth were obtained by Fox at Munja Station from a younger aboriginal who was an " owner " of the gallery.

Myth.

In primeval times Kalingi set out from Noala and went up the Calder river. He stayed for some while at the Calder Junction, then went up the Backten Creek, passing along the rock wall where there are now the paintings. Higher up he found many flying foxes and killed all of them. On his return he made the great waterhole. In it he made a large abode with an Ungud camp and a Wond'ina camp. Then he went to the west shore to " fix it up "; but all the stones fell down into the water (as a matter of fact, the shore opposite the rock wall is studded with large boulders). There he set up a monument (d'álalo) to record his sojourn, and went over to the other shore to fix up that. There he turned into Ungud. When Kalingi turned Ungud, the fish-hawk turned Wond'ina.

The Maliba I. Gallery

Locality.

The gallery is situated east of the Calder river. Dr. Petri rendered the name by " flat stone ". Taking flat as synonymous with even, this might be an allusion to the smooth upper surface of the rocks adjacent to the right. It is, however, more likely that the name refers to the gallery itself with its roof overhanging at a little distance from the ground. As the paintings start right at the foot of the rock, the best way of taking photographs was, putting the camera on the ground, to lie flat by the side of it.

Principal painting.

Numerous large Ungud serpents are here concentrated (Pl. XVIII.). Starting at a chasm, they appear to be coming out of the rock. Two cockatoos with large heads and quite upright bodies seem assimilated to the serpent portraits (Pl. XIX.). The bending of their heads, however, as well as their legs and tails mark them as birds.

Further representations.

Two large Wond'ina heads above the ground (Pl. XX.) are equipped with forked lightning signs. Originally three of them stood side by side; but the right one is unrestored. On the frontal part of the projecting roof three more Wond'ina heads were lined up of which again only the left and middle ones are preserved; the right one, since almost obliterated, must have been unrepainted for a considerable time. The same holds of about a dozen Wond'ina heads of medium size which, scattered over the stepwise rising and projecting rock wall, are weather-worn partly beyond recognition. Only three, framed with lightning signs, are in good condition. They are moreover remarkable for being so painted on three rocky bulges that their foreheads coincide with the convex part of the bulges, thus coming out plastically.

Of the animal pictures few are repainted. On the lower right, the anterior one of the two large kangaroos is fairly perceptible. A small tortoise higher up, underneath the cockatoos, is effectively freshened up; the dot-filled circles inside the body represent its eggs (Fig. 25*c*). Three items to the left of the tortoise seemed at first puzzling (Fig. 24). Their signification came home to me later at Bind'ibi where there was opportunity to compare a similar, more elaborate, and well-interpreted representation of timbi, the owl-like night-bird. Between the plastic Wond'ina heads are seen very old drawings, partly peeling off and partly blown over with white, of a lizard (Fig. 25*a*) and a long-necked

tortoise. Although the latter animal figures in the myth following below, it must have been for a very long time unrestored. Our rare finds of pictures of the long-necked tortoise (Frobenius gallery, Kobuda; Fig. 25*b*) were in fact invariably old and faint. Near the leftmost plastic Wond'ina head stands that little figure an analogue to which was seen in the Frobenius gallery.

Myth (from Dr. Petri's notes; unprinted).

Once Kaluru, coming from the great salt water, wandered down the Walcott Inlet and the Calder river. In the Kurkan Mountains he caught a long-necked tortoise in the little billabong Didiwar. That was near the Maliba rock-shelter, so he made that his camp. There is a banda-odin of Kaluru; there, they say, he turned into the Ungud serpent.

Mangangu

Situation.

Mangángu, in the tambun Mónyol on the middle Sale River, is 2–3 miles north of Sale River Station. The rock is far overhanging very near the ground.

Principal painting.

A large serpent, 2·70 m. long, is painted on the ceiling (Pl. XXI.). Its broad body emerges over a boulder in plastic roundness, two rocky bulges being incorporated in the picture by placing into the deepening between the two elevations a bent piece of the serpent's body.

Minor figures.

Beside the broad triangular-pointed tongue is a small sketchy drawing of a fish. Below it are two hanging bats.

Myth (from Petri's unprinted manuscript).

Nomúrngun, an evil Ungud serpent, came from the other side of the Prince Regent River, everywhere killing many men in order to devour them. In the Kalurungari country on the Calder river he meant to camp in a rock-shelter and to make an image of himself. This was prevented by the Ungud Nyodon ("Snake's-kidney-fat") who had already established his own camp there. Nomurngun went on devouring more people. He arrived at Bandid'en with a full belly. Being tired he lay down. There he urinated three billabongs. In Mangangu he left his shadow behind on the overhanging rock and went down into the

earth. But for Nomurngun's portrait, it is believed, the stone would fall down. The same thing would happen on making a noise there. In a near-by rock-shelter Nomurngun slew many people for the crying of a child.

Maunginga-Odin

Situation.

Maungínga-odin, in the tambun Nalar on the upper King Edward river, is situated in the same massif as Bradwodingari. Although the two galleries are not far distant from each other, there was no evidence of any mythical connexion between their paintings.

Stone arrangements.

On top of the rock a stone is set up in the way of a menhir. That, the aborigines say, is the Maungínga Ungud rising from out the rock and overlooking his country. (From Petri's unprinted manuscript).

Principal painting.

This is the fourth gallery, as far as our finds are concerned, where an Ungud left his shadow behind in the shape of a serpent (Pl. XXII.). Maungínga is the mythic hero of the black-headed serpent (*tamalar ngari*). The restored part of the serpent's portrait is small, only a short piece of the longitudinally hatched body being visible. The dark head, because the largest black area, is prominent. The thin tongue is tripartite. The Wond'ina in half length on the right below the serpent seems to have an intrinsic part in the embodiment of the primeval hero of this gallery. The lightning sign round his ochre bow is unrestored. An almost identical Wond'ina half-length on the left-hand side is rather weathered; it seems to be the old representation of Maunginga. A large serpent with raised black head is parallel to the lightning sign round the Wond'ina head.

Secondary figures.

Ten Wond'ina heads of various size between and beside the half-length portraits are repainted; faint fragments of ochre bows are still visible above. The irregularly shaped ovals with bristling little strokes at their lower part, painted in three rows on the right-hand side, were interpreted as a tuberous fruit, *melar*.

Animal-Shaped Wond'inas

Jándara

Locality.

Jándara is situated near the Glenelg river, on the left, that is south, side of it. As far as this region the salt water flows up the river with the rising tide. From Mary Springs the rock-shelter can be easily reached in a day's riding. A low massif is so hollowed out on its west side that perfectly smooth horizontal surfaces have formed under the far projecting rock (Fig. 26).

Stone arrangements.

Opposite a cave where bones are deposited, a little beyond the range of the overhanging rock, there is a thin slab, 52 cm. high, set up between some blocks. Polished oval stones are heaped underneath a lying Wond'ina figure. In addition there is a smooth slab marked with undulating lines which seem produced by the action of water, a phenomenon which struck us here and there in the stony ground of Jándara as a local curiosity.

Principal painting.

One of the straight plane ceilings bears the portrait of the patron Wond'ina of the shelter in the shape of a large, 4·35 m. long crocodile (Pl. XXIII*a*.) The white stripe across its body is apparently to represent a hair-belt such as are worn by the anthropomorphous Wond'inas. From the large rounded eyes a much lengthened nose reaches down to the end of the snout. Two semi-circles round the eyes are reminiscent of the customary ochre bow. Thus traits of the Wond'ina face are blended with the crocodile's head.

Secondary figures.

A small crocodile is lying in front of the large one's hind leg. In front of and below the crocodile's head, a group of figures is placed partly on vertical surfaces and partly on the vaulted ceiling. A squatting woman with legs wide apart occupies the space between the crocodile's jaws and a native companion (Pl. XXIV.). Between the latter and the uncoiled big serpent is interposed the half-length portrait of a large long-billed bird which resembles the native companion, except that the outspread wings characteristic of the latter are absent. In the lower row, to the right, two wallabies are sitting face to face. Two fishes next to the wallabies are repainted while others, further to the left, have remained in faded condition. Further up, the next

figure is effectively restored. At first suggesting a tortoise, it turns out to be one more specimen of the squatting woman type. A crocodile on the ceiling, further to the left, is painted on top of such undulating lines as were mentioned above as a peculiar feature of the Jándara sandstone which is rather slate-like in its stratification. These lines in the stone look like water in motion. As the crocodile is painted over it, it seems to be swimming in the water. A few faint individual figures further to the left are repetitions of motifs already described. On the extreme left is seen a crowded row of small snake-like figures. They are reminiscent of the representations of the lambaras, those edible larvae, but do not entirely agree with the so interpreted designs in Wólang-Kolóng and Kand'álngari; the latter are shorter and round at their lower part. The signification of these figures here as well as in Kobuda (see Fig. 29*a*), therefore, is doubtful. On the right-hand side, under the principal crocodile portrait, human bones dyed with ochre lie in front of a very low and apparently deepening cave. They were originally bundled up in paper bark and weighted with stones. Wallabies and bandicoots are blamed for upsetting the arrangement. Narrow steps in the rock on the left of the ossuary bear faint drawings of seventeen larger dot-filled circles representing bush fruits and of nine animals. The latter resemble the representations of porcupines, though they are in horizontal position whereas in general porcupines are painted upright. This deviation may be due to the narrow painting space available.

On the right-hand side of the ossuary are the largest vertical paintings of the Jándara gallery, namely two Wond'ina figures lying head to head (Pl. XXIII*b*.). Only the two heads and the rudiments of a longitudinally hatched body ornamentation in the left one are repainted. The latter one's arms held close to the body, his hairbelt, legs, and feet are fairly perceptible. Three half-length Wond'inas are showing over his body, and about ten Wond'ina heads can be perceived in the intervals and by the side, together with numerous extremely faint traces of very old ochre bows. This wealth of designs is painted on the ceiling which rises right above the lying Wond'inas. At the lower left, the painted surface is bordered by a double and partly treble dense row of tiny heads probably representing "spirit children". Underneath are laid down the stones belonging to Wond'ina. The body of the right lying one disappears almost entirely under the white blown over it: then, on the white ground,

only the head was effectively restored. Nearly above the legs are painted two birds of which the lower one is in bad condition (Fig. 47*a*).

Myth.

The following myth was told at Sale River Station by an Ungarinyin.

> " An old Wond'ina Garangala was the maker of the rock-shelter. The waterhole is about half an hour distant; in it lived a large crocodile. One day it left the water and went to the shelter where Garangala was. The crocodile lay down on the ground. As it was lying in front of him, the Wond'ina painted it on the rock ceiling. When Garangala had finished, the crocodile went back to the billabong. There they are, the two of them, to this day."

It is remarkable that here the mythic being survives in the waterhole as Wond'ina. In most stories the Wond'ina turned Ungud before going down into the earth.

The Crocodile-Wond'ina was reputed evil. On the eve of our departure from the gallery, Gerda Kleist carrying boiling water stumbled and scalded her foot. To the aborigines it was an established fact that the Crocodile-Wond'ina was responsible for the accident.

Tegulan-odin

Locality.

Tégulan-odin, or " frilled lizards' images ", are found in the tambun Prèmunánban on the upper King Edward River, painted into a niche which, in a huge sandstone block with a generally rough and brittle surface, offers a smooth ground.

Principal painting.

The largest figure is the Tegulan-Wond'ina at the lower right. His head is distinguished from those of the other tegulan by a vertical stroke passing between the eyes across the forehead; I could not, from the photographs at any rate, make out such a stroke anywhere else. The most Wond'ina-like feature is the treatment of the shoulders with arms hanging down, whereas lizards always stretch out their forelegs beside their heads. The longitudinally hatched body terminates in a crevice so that the figure appears to be rising from out of the rock. Twelve frilled lizards of slightly different size are so closely surrounding the

Wond'ina—with whom they were, moreover, simultaneously renewed—that the ensemble of these intertwined figures may well be regarded as the one principal painting. Two rows of eggs are drawn inside each body of two smaller frilled lizards.

Minor figures.

On the photographs, the faded earlier representations are hardly discernible seen beside the keen white of the restored frilled lizards. On the upper left, an animal facing to the principal group may be a dingo. Some oval and round forms may represent bush fruits.

Kobuda

Situation.

The Kóbuda gallery is about half a mile west of Glenelg and about 13 miles south of Wurewuri on the pathway to the Sale River Station. One first descends to the great waterhole Dsiringalla. The waterhole has a shining green colour; the rocky shore, rising on three sides, an orange-red patina. One then walks round the hill on the other side of the declivity to reach the picture gallery on top of the hill. It is situated in the internal angle of two rocks which are nearly perpendicular to one another.

Stone arrangements.

On the shore opposite the gallery, at the foot of the declivity, are heaped up half a dozen polished oval stones. They are of lighter colour than the surrounding rock in general; some are broken. It is a Wond'ina monument such as are the upright slabs set up on large horizontal boulders further up.

Inside the gallery the common polished oval pebbles are lying on the left-hand side of the angle formed by the rocks, some in a hole which by its size and rounded shape resembles a ship's bull's-eye, others on a rocky shelf.

Principal painting.

On the left-hand side a large pair of eyes is painted on a projecting wall and screened by the roof immediately over it (Pl. XXXVI.). Two broad strokes issue from the eyes and vanish higher up. Dotted rows are arranged below the eyes, radially, and above, horizontally. They are partly repainted, partly come out pale through the blown-over white (Fig. 28). Traces of a red semi-circular frame are too vague to allow the

original shape to be restored. Perhaps the design was previously enclosed by a broad or multiple narrow ochre bow. Sets of dots on the left-hand side, dimmed by the overlaid white, are indefinable.

Right underneath the portrait of the Ant-Wond'ina, where the stone has cracked off, a horizontal smooth surface has formed which bears the drawing of a squatting woman. This is the largest and most elaborate representation of that frequent motif. The rock wall, over a few metres' length to the right, is entirely fissured. This is the place of the bull's-eye hole with the oval stones. On the slanting lower part of a rocky bulge, six ovals, irregularly shaped and about 50 cm. long, are painted over with light-reddish ochre. The aboriginal after some hesitation interpreted these ovals as yams. There are further oval stones lying underneath.

Exactly in the internal angle of the two rock walls is a small, low, but rather symmetrical cave. On its ceiling a little Wond'ina stands between animals. To do the painting the artist must have assumed an uncomfortable position. The Wond'ina has tiny arms and overlong feet. On his left shoulder rises a long, wide-forked lightning sign. The bending of head and body conveys some peculiar animation to the figure. The wallabies too are pictured as if they were bustling about. Such liveliness distinquishes this representation to some extent from the rest of the Wond'ina paintings. Between the repainted wallabies, older drawings are discernible through the blown-over white. Serpents, tortoises, and—oldest item perhaps—a long-necked tortoise are motifs here no longer preserved. At the right and left corners of the small cave are pictured wallabies with their young in their pouches. An older drawing perceptible below the animal mother is reminiscent of the previously mentioned figures possibly representing lambaras (cf. p. 38). The encircling bow rising over amidst the head of the Wond'ina on the lower left may perhaps represent a lightning sign. Higher up, a serpent is winding slantingly towards the upper left. The combination with a similar serpent occurs in the group of wallabies at the left edge of the cave.

Myth.

In front of the above-described principal painting the aboriginal guide remarked spontaneously: This Wond'ina was particularly averse to women. They were strictly forbidden to

enter his gallery. The drawing underneath the ant's head was to remind of a woman who in spite of this restriction came here and was killed for it by the Wond'ina.

There was found in Kobuda, finally, an almost indiscernible small old monochrome painting (Fig. 42. Cf. p. 47).

Totem Representations

Tegulan-odin

Locality.

Tégulan-odin, " frilled lizards' images ", in the tambun Nalár on the upper King Edward river, are found inside a low cave at the foot of a large massive rock which is capped by a flat stone. The largest and best-preserved painting is placed on a bulge between the vertical socle and the nearly horizontal ceiling.

Principal painting.

Two frilled lizards with broad tails and legs spread around are combined with a number of yam tubers (Pl. XXIX.). Animals and plants agree in their surface pattern and in the colouring of their heads.

Secondary figures.

A large yam like a two-rooted tooth and a frilled lizard with head turned downwards are drawn on a vertical wall which, as far as Petri remembers, projects at a right angle to the principal group (Fig. 30).

Warana-odin

Locality.

Warána-odin, " eagle-hawk images ", are painted on a large detached boulder. To reach the latter one has, coming from the passage under the portrait of Walanganda, to turn to the left. A flat hollow makes a fairly rounded niche which has been selected as framework for a concentrated set of paintings.

Principal painting.

A number of the large birds are painted so low that they appear to stand on the ground. Another group, further up, seems to be entering the rock. The two eagle-hawks to the left, holding an indefinable black-dotted red something between their beaks, show an almost heraldic arrangement. Between them a wallaby stands upright. Above, two eagle-hawks turning back to back form

a triangle inside which appear a small Wond'ina head and, on top of it, a larger one. The upper one has white ondelon in its ochre bow and a tall red cockatoo feather rising amidst it. Two Wond'ina heads on the lower right are unrepainted.

Secondary figures.

These paintings are so interwoven with one another that the distinction between principal and secondary figures is here hardly tenable. In this respect we may refer to the particularly striking grotesque anthropomorphous figures called by the aborigines "devil-devil" and described by them as bush spirits, dreadful especially in the dark. When once our aboriginal attendants were to fetch water occasionally by night, they set fire to a tree on the river bank so as to keep the devil-devil away with the light.

Myth.

The aborigines who took Petri and Fox to the picture gallery did not know the mythical story of this painting. They only said that the Warana Wond'ina had here gone to heaven and was still visible there as the Southern Cross. A myth of Warana, without specified locality, is related by Capell[1]: Wodoi had stolen the two laid eggs from the eagle-hawk's nest. Warana chased the thief. The latter's companion, D'ungun, taking up boomerang and club, intervened, and when the pursuer was tired, killed him. Warana turned into a rock painting, the eggs into two stones said to be visible in front of the painting.

Paintings in North-Eastern Kimberley

About 3 miles south-south-west of the new Drysdale Mission Station lie two rock-shelters, both of them known under the name Gra Anumeri. *Gra* is the equivalent Kulari word to the Ungarinyin *tambun* which means the territory of a horde. In Anumeri II., about 150 m. up the valley, Fox came across what are the only two Wond'ina paintings among our finds in Northern Kimberley. According to the local aborigines, Kulari and Kulinyi, these paintings represent Kaluru.

Two different interpretations were offered as to a representation (Fig. 32) in the Langanana rock shelter, in a long, narrow sandstone ridge about 2 miles north of the old Drysdale Mission Station. On the one hand, the painting was interpreted as "yams and the sun"; on the other hand, the form seen on the left was described as a mai-angari. Both interpretations may be correct.

1. A. Capell, Mythology in North-West Australia, 1939, Oceania IX.

assuming that mai-angari stands for yam. In Malán a motif which in every respect resembled a complete painted mai-angari was defined as wild honey (cf. p. 24). An outline of similar shape on the middle King Edward River was interpreted as mai-ángari. Mai-angaris, then, are not an entirely uncommon subject of these paintings; among the engravings found near Port Hedland sacred boards are even frequent.

White colour is applied in the two Wond'ina paintings in grounding, in " yams and the sun " in the drawing. It is absent in the following groups of figures from the vicinity of Drysdale. A drawing from Amuneri I. (Fig. 33) seems to me related in motif to the Wond'ina paintings. Yams and a crocodile are represented beside a long rod-shaped figure and seven rod-shaped little mannikins.

An outlined figure from the Langanana rock-shelter (Fig. 34), considerably larger than six partly-painted attendant figures round it, was once interpreted as d'imi (bush spirit) with children, and again as a father of Drysdale Mission taking a walk with aboriginal children. They are, however, drawn lying, while we should deem upright position essential to walking persons. The aborigines don't seem to worry much about that, which illustrates the great diversity of point of view in the rendering of the surrounding world. Another drawing of the same provenience (Fig. 35) represents the persons similarly, but in upright position.

A grotesque picture (Fig. 36) was found in the more northern Kanbudjoadángi rock-shelter II. in the Gra of the same name, about 100 m. east of the pathway between the old and new settlements of Drysdale Mission: A child sucking a woman's giant breast. The group, to judge from the bright colour, does not appear to be old, but it is in bad condition. Petri when inspecting the original was struck with the impression that it was very old, and the same opin'on he formed as to the rest of the paintings. It then turned out that the local aborigines know nothing about it. With noticeable indifference they invariably declare these figures all and sundry to be d'imi, that is, bush spirits. Thus these paintings present the same difficulties as most of the rock paintings which have come down to us from by-gone peoples about which we know little or nothing. A proportionately large group (Fig. 37) is painted on a lofty boulder in Kanbudjoadángi I., about 3 miles from the new mission station and some 300 m. from the abovementioned rock-shelter in the same Gra. Although the various shades of individual figures might as well be due to the more or less thick layer of paint, chronologically different strata can be

distinguished. The most faded figures are, moreover, smaller and not so simply drawn in plain strokes. A straddling figure beside the squatting woman is likewise obviously older.

Faded human figures resembling the older ones arranged in groups are also found single. The example from Anumeri I. displays a similar posture as the figure beside the grotesque woman (Fig. 39). In Kanbudjoadángi II., the squatting little figures are painted on the ceiling. To the same type of paintings belong Pll. XXXI*a., b* and XXXII*a., b.* Unfortunately the photographs are very blurred. Petri's note-book with pertinent sketches was destroyed in a bombed cellar.

The unsatisfactory reproductions are included in this publication on account of the particular interest we think these finds possess. They immediately suggested to us Mr. Bradshaw's drawings of his strange discoveries on the Prince Regent River. In spite of some improbable details Bradshaw's paintings so convinced us that we inquired and searched for them throughout our expedition. We were not, at that time, aware of C. P. Mountford's good reproductions. Only at the very end were our hopes fulfilled. Unfortunately our examples are few; but at least they prove that a different style than that of the Wond'ina paintings does occur in the Kimberleys. All these pictures of a different kind we at first called " Bradshaw paintings ". That is a makeshift designation possibly covering representations which on the strength of wider knowledge may turn out to lack any connexion.

Old Paintings in Central Kimberley

Our search for old paintings was even less successful in our southern area of research. Perhaps we had here reached their outermost line of diffusion. That at any rate is what the Ungarinyin's story seems to suggest (see p. 47). I found the paintings in the last but one shelter I visited on the lofty rock of Malan. The faded paintings are placed on vertical steps screened by projecting stone near the centre of the rock. Obviously these surfaces were the first, because the most suitable, to be painted. On this rock, then, where there are Wond'ina paintings as well, their location proves the monochrome human figures to be older. Apart from their weather-worn condition, their age is confirmed by the aboriginal's statement.

The tall bent figure in red ochre comes out only vaguely on the reddish rock (Pl. XXXIV.). Some uninterpreted signs in front of the arms differ slightly in colour, being rather violet. The thickenings of the arms and the cords with tassel-like ends have their analogies in Bradshaw figures.

An elongate figure enveloped by shapeless colour patches is vanishing in remnants of ochre pigment; no legs being drawn, the resulting effect is that of a long gown (Pl. XXXV*a*.). It is obvious to the eye that the pigment was applied in stripes, which betrays the use of a thin brush-like instrument such as a bird's feather or a twig with chewed end. On the right-hand side two sets of three branch like forms each stand out in dark reddish-brown. On the lower left is a smaller and more rectilinear reiteration of the large figure (see also Fig. 11*a*). The significance of the design on the right hand side remains obscure.

Fragments of paintings in the interval between the two figures copied and on either side of them are hardly decipherable. A number of figures are painted at the top of two elongate horizontal red rectangles from which they are almost unmarked-off. Between these figures recurs another and considerably smaller iteration of Pl. XXXV*a*., about 27 cm. high. Striding figures—if correctly so designated—are about 30 cm. high in one instance and no more than 10 cm. in another.

Clusters of human figures are painted on the opposite, that is, east side of the rock which is reached by passing the tunnel. Fewer shelters have formed here, and there are no Wond'ina paintings. On the vertical piece of a rocky step, under a far projecting roof, crowded figures can be perceived, though only a few individually. A striking feature in the best-preserved of these figures (Pl. XXXV*b*.) is what seem to be rudiments of wings under the arms. Sporadically light contours are discernible round the red body areas.

The winged figure recurs further down where two white irregular ovals are painted on top of an upright figure. Several figures are marked with yellowish-white contours; there is no vestige of this feature on the west side.

The branch like motifs (Pl. XXXV*a*.) occur on the east side repeatedly; in one instance a cluster of several is crowned with a bundle of long delicate white lines. On a single stone which must have fallen off the rock wall, the branch-like motifs, 32 cm. high, are found together with an outstretched arm.

Unfortunately our photographs are too blurred for reproduction. The original prints confirm the copies here reproduced. Three figures of which no copies were made are here given in photograph. They have an amazing resemblance to certain South African rock paintings. An example of these is here shown in juxtaposition. One should expect to find the two specimens in

adjoining districts rather than on two continents separated by the ocean. In pointing to the fact, we are far from attaching any scientific value to it. We certainly do not mean to imply that the curious coincidence can be taken as evidence of culture contact between Australia and Africa.

Concerning the old paintings our Ungarinyin guide to Malan had little to tell. Pointing east he said: That way are many more rocks high up the hills like Malan, with similar paintings. The black-fellows have nothing to do with them. Long ago Kujon, a black bird, painted on the rocks. He struck his bill against the stones so that it bled, and with the blood he painted. He painted no animals, only human-shaped figures which probably represent spirits. It is long since he did so.

In close proximity of the great Malan rock shelter the aboriginal found some solitary old figures in faded grey-violet, painted on the vertical walls of a small canopied niche. The attitude of these figures (Fig. 41) is reminiscent of Pl. XXXV*a*. The tallest (Fig. 41*a*) stands obliquely under an elongate painted oval on one of the lateral walls. The other wall, at a right angle to the former, bears the two neighbouring figures (Fig. 41*b*) and one of those tiny striding figures (15 cm. high).

In some striking features there is perfect agreement between these pictures of Malan and the drawings reproduced by Mountford. His figure No. 30 resembles our two specimens (Fig. 41*b*) except for their heads: Short arms are slanting down from bodies the shape of two long vertical stripes. The uncommon shaping of the lower part of Mountford's No. 31 resembles the central part of the unelucidated paintings (Pl. XXXV*a*., right), only that there are here more numerous and narrower stripes bending round the straight central one. If I am not mistaken, there are even branch-like forms coming out from behind the neck. Such correspondence is the more astonishing taking into account the considerable distance between Malan and the Drysdale River Mission. It seems to me that like traits so peculiar must have sprung from like specific ideas; hence they must be indicative of cultural connexion. It may be assumed, then, that one culture once extended over the area between the picture places known to us and that further evidence of it may be found there.

A design which unfortunately is most fragmentary comes from Kobuda. The very faint reddish-violet lines hardly allow of interpretation. The upper part of a central figure with arms stretched out laterally seems the safest item to identify. On the left-hand side I seem to perceive fragments of two figures

raising their arms. The leaf-like cross-lined form on the upper right recalls similar designs below an animal figure in Koralyi (Fig. 5). For the loosely arranged parts of a quite dubious representation on the lower right a comparison with the old vegetable-like design in Modum may perhaps be illuminating (Fig. 42). Also an old painting from the vicinity of the Drysdale Mission may—we are suggesting it with due reserve—find its best explanation as a vegetable motif (Fig. 43).

The rock paintings of the Bradshaw type seem to have no relation to present-day aboriginal culture. No interpretations are at hand such as the traditions the Kimberley tribes provide for the Wond'ina paintings. The Bradshaw paintings, therefore, must, for the time being at any rate, be reckoned as prehistoric finds, which implies all the difficulties confronting the investigator of art of unknown provenience. This state of things may change if a greater number of paintings in the Bradshaw style and by good luck fragments of pertinent traditions should be discovered. For anthropological research has shown, precisely in the Kimberleys, that the aborigines did not preserve their old-time culture in never-changing, rigid forms.

Between the fresh-kept Wond'ina and the "Bradshaw" paintings there is a tremendous difference as regards style, technique, and objects represented. But inconsistent as the two styles of rock painting appear in their more typical examples, we still find intermediate forms of technical process.

There are indeed a number of Bradshaw representations which are like the old paintings in so far as they are set directly on the rock wall, and not on a white ground—although they are less weather-worn—and which may be compared to certain Wond'ina paintings such as "The alluring figures" (Fig. 12). A number of white-contoured small figures seemed familiar to our Ungarinyin attendant who unhesitatingly interpreted them as frogs. The customary ground is absent also in the ghost-like little beings, interpreted with a sure command of detail, in Koralyi (Fig. 44); white colour is here applied like red in line-drawing. In the old Frobenius gallery even a local totem animal, a long-necked tortoise, is throughout painted red and edged with a light contour. Finally in Kalingi there were serpents and yam tubers in faint condition and without application of white, though otherwise very much like those restored on white ground. Such observations suggest the question if there were earlier paintings, equal or related to the existing Wond'ina paintings in form and significance, but devoid of the white ground.

Petri, in his investigations, paid special attention to processes of cultural change. He was able, in various areas, to study initial and advanced stages in the development of new ritual pattern promoted by the younger men and tending to oust established cults to which the older people adhere. Also the migrations of certain corroborees show that ritual forms of ancient tradition undergo changes. The same body painting and head dresses which, in the north, were requisites of a sacred dance performed only among the initiates, reappeared further south as stage properties in a corroboree play which was very popular at the time of our expedition and which we saw both at Munja and Sale River Station.

In the last chapter it will be shown that among the seemingly uniform motifs of the Wond'ina paintings there are some older and now discarded form elements.

These facts suggest that it might be possible also in the study of rock paintings to trace earlier developments of customs and styles by more numerous finds and continued inquiries.

I would mention a hypothesis suggested to me by the skeleton appearance of some " Bradshaw " figures. A skeleton-like body painting is a requisite of some corroborees. In the belief of the Kimberley tribes it is the dead who inspire a new corroboree in the medicine-man. His *ya-yari* goes to the realm of the bone souls. There he is shown the figures of the dance, the pertinent body ornamentations and dance implements. When returned to the earth, he will teach them to the men of his community. This ensemble of ideas has nothing to do with the Wond'ina paintings. There seems to be some affinity, however, with the old Bradshaw figures. Perhaps other methods may yield further evidence that the spirits of the dead once dominated aboriginal imagination more than is obvious to-day.

Observations on the Wond'ina Paintings

In trying to understand these strange pictures, it should be borne in mind that they do not reflect present environment, but illustrate mythical traditions of primeval times. Accordingly all features of Wond'ina's appearance are significant. For instance, as has been mentioned in the Introduction, the red ochre bow was explained as blood, the white face as water, which substances filling each half of Wond'ina's body, endow man with strength and nature with fertility. According to other versions, the ochre bow is equivalent to the rainbow; in this connexion a second bow on top was interpreted as rain-cloud*. More often the bows

*From Petri's unprinted manuscript.

over Wond'ina heads are interpreted as signs of lightning (for instance in Kalingi, Pl. XVII.). Lightning signs are indeed attached to many Wond'inas, but they do not belong to their standing attributes. They occur also as broad, flattened, furcated bows over the heads (Koralyi, Maliba, Kobuda). In Malan the lightning sign is wound round Wond'ina's arm serpentine fashion. Similarly postured serpents accompany two lying Wond'inas in the Brockman gallery at Bind'ibi, where the serpents are distinctly marked as such by their heads, but are otherwise almost beyond recognition because for a long time unrestored. Under the image of the serpent the lightning sign was frequently represented on the old sacred mai-angari boards.

The black ovals on the breast of the Wond'inas most aborigines were at a loss to explain. Occasionally these ovals were interpreted as breast bone or as heart or as the " medicine " Wond'ina keeps in his body. Professor Elkin mentions an interpretation as a pectoral such as, for instance, a pearl bowl.

For the body surface design too—red stripes and rows of little strokes or dots—various explanations are available, for instance as body painting or as rain. A myth of some primeval Wond'ina having painted himself like that and thus made rain would justify both interpretations; but nothing of the sort has come to our knowledge. An interpretation Petri got repeatedly was that the body surface design represents Wond'ina's beard. This Petri considers the more valuable statement, partly because there was agreement of several informants, partly because a long beard is an important attribute of mythical beings in various Australian traditions and plays some part also with other tribes just in rain-making. Occasionally the body surface design departs from the common scheme of longitudinal hatches or dotted rows. The two large Wond'inas of Malan A and B are partially painted with sets of parallel strokes, running in curves and meeting at an angle. They are to some extent reminiscent of the Western Australian tjuringas the surfaces of which are engraved with opposing sets of lines. Many such boards have come from the desert into the Kimberleys through intertribal trade. The assumption may perhaps be justified that indigenous Wond'ina painting has been influenced by such imported decorations.

The myths associated with the galleries refer to their principal figures most of which are conspicuous by their size. The more or less numerous minor figures representing the totems of the clansmen are rarely mentioned in these myths. They are not linked with the principal figure nor with one another by any relation derived

from primeval times. This may account for the fact that, as a rule, the principal figures seem to be restored without alteration, while the drawings of animals and plants allow of alteration. Once an old totem is no longer represented in the community or a new one arising[1], an old motif is dropped or a new one added.

Most frequent among the animals are kangaroos (Fig. 23) and wallabies (Fig. 29). The large kangaroo species are one of the pairs of social totems from which the moieties of the Ungarinyin are named.

The birds which are likewise numerously pictured are believed to be especially near to Ungud. They were the first to be endowed by him with speech, whereas the rest of living beings learned to talk only later.[2] There is in the rock paintings a variety of bird types corresponding to the many species of Australian birds. The significance of the portraits of the especially sacred owl-like night birds (Fig. 24) is by no means obvious. It seems Wond'inas too are sometimes owl-eyed (Pl. VII. and Fig. 15). One soon gets familiar with the various types of birds: The large native companions (Fig. 14 and Pl. XXIV.), the eagle-hawks (Pl. XXX.), the cockatoos (Pl. XVIII.), all sorts of aquatic birds(Figs. 41*a*, *b*; 42*a*, *b*, *c*). The two animal species which we found nowhere restored are the porcupine and the long-necked tortoise. The former is represented in the largely weather-worn Frobenius shelter (Fig. 9*a*) ; it is repeated nine times in a row, but is scarcely perceptible, at Jandara (Cf. p. 38). Three porcupine drawings in the Brockman gallery at Bind'ibi are vanishing because peeling off with the white ground, as can be seen in Fig. 43. The invariably old pictures of long-necked tortoises are reproduced in Fig. 25*b* and Pl. XXVIII. The specimen in the Frobenius shelter can be supposed to be the oldest because of the absence of a white ground (Cf. p. 48).

The Ungud and Wond'ina paintings in Kalingi show how established forms, memorized again and again, have been faithfully preserved. There is no difference between Brockman's photographs of the big serpents, taken in 1901, and ours, taken in 1938, any more than between the respective reproductions of the Wond'ina Nyandugaiali (Pl. XVI.).

On the other hand, we observed alterations even in Wond'ina representations. All fresh-painted heads, apart from those rare owl-eyed ones, are fairly alike. In the Mount Hann district a somewhat different type of face prevails, marked throughout by slender

1. These questions are discussed in detail in Petri's unpublished manuscript.
2. From Petri's manuscript.

noses reaching up beyond the close-standing eyes. The ochre bows are covered with white spots. Again a number of old Wond'ina heads seem to have another type of face in common: Rounded eyes and a rounded nose characterize the painted-over head in Koralyi (Pl. II. and Fig. 16*b*), the Tortoise-Wond'ina at Wolang-Kolong (Pl. III.), the upright Wond'inas in the Frobenius gallery (Pl. V. and Fig. 9*a*), the head beside the rain cloud in the Brockman gallery (Fig. 9*b*), and two nearly imperceptible heads in the same place which seem to have belonged to upright figures (Fig. 43). The features of these weather-worn examples from earlier strata come out more clearly in the left and middle ones of the plastic Wond'ina heads in Maliba (Pl. XX). Here it is obvious that their rounded eyes have no lashes, but are bordered only by a number of small dots. The eyes of those weathered figures too seem to be mostly lashless; a dotted line is more likely to have vanished, leaving no trace, than strokes representing eye-lashes. Incidentally, the above-mentioned two plastic heads at Maliba are older than the third to the right, which was supplied with eyelashes when restored, and than other more recent paintings in this gallery; thus they too have not been "touched" for a considerable time. Fresh-painted heads with rounded eyes we found only with Kaluru, the so-called lightning-man, in the Brockman gallery, with the animal-shaped Wond'inas at Jandara (Pl. XXIII*a*.) and Kobuda (Fig. 28), and with all Ungud serpents. The Kaluru portraits in the vicinity of the Drysdale Mission are lashless and only bordered with dots (Figs. 31*a, b*). Very old pictures with rounded eyes were found by Mr. Coate in Central Kimberley. Our collected material, pictorial and mythological, provides no clue to these observations. They may still be useful in further investigations.

The larger distance between rounded eyes and nose as found in older representations recurs once between oval-shaped ones in the portrait of Brad. The suggestion which has been made that Brad may be the exceptional case of a Wond'ina with a mouth can, I think, be dismissed by referring to the older type of Wond'ina heads.

Another instance of changing representation of the mythic heroes is the obsolete encirclements of the ochre bows of some Wond'inas. They were not mentioned by most interpreters. Probably they represent clouds, though some specimens would rather suggest a feather-dress, a forerunner of the differently-painted cockatoo feathers now customary. For this adornment,

frequent in restored paintings, occasionally resembles in outline the old cross-lined bow forms, e.g., the red-and-black-painted feathers on the head of the lying Wond'ina in Koralyi (Pl. I*a*.; also for two specimens Fig. 16*b*). The interpretation of these ornaments as cockatoo feathers was given very positively, and it was invariably repeated wherever we came across that accessory, e.g., as to the Wond'ina with the marsupial mouse and his more slender cockatoo feather in Koralyi and as to a lying Wond'ina in the Brockman gallery. In Yangalu we find on top of the weathered upper Wond'ina the old encirclement of long cross-lined bows (Pl. VIII.), underneath, however, on the restored " pretty fellow ", four very long and slender cockatoo feathers, two at each side of the ochre bow (Pl. IX.). Finally the old and new motifs coincide in Walanganda (Pl. X.; Fig. 16*b*).

The repainted ochre bow with two cockatoo feathers is set off by the blown-over white against the earlier painting. The latter is not, however, composed of individual cross-lined figures arranged in a semi-circle such as are fairly perceptible in Malan (Pl. VII.) and Yangalu, resembling cockatoo feathers; the curved lines above Walanganda are rather like those interpreted as clouds above the old head in Koralyi (Fig. 16*a*).

In a different way the well-known cockatoo feather motif is combined with versions of the older unaccounted for motif in the encirclements of two lying Wond'inas. In Malan A (Pl. VI. and Fig. 13) a tall cockatoo feather over amidst the ochre bow is margined by close-standing, cross-lined, slender figures. While the latter are somewhat weathered, the feather dates from the latest painting. It might, therefore, cover some other central piece which would account for its unusual length, say, a serpent done simultaneously with the lateral figures and forming part of the original design. Similar reflexions as to what was originally represented or intended are evoked by the large bow round the head of the lying Wond'ina in the Frobenius shelter at Bind'ibi (Pl. IV*a*.), as its shape is suggestive of clouds (see, for instance, Pl. II.). The middle " cockatoo feather " is a broad-margined bow. There is no evidence whatever, on the photograph, of serpents instead of feathers reasonably forming part of the picture of clouds. I did not then—in the early stage of our expedition—examine the original for this point. The occurrence of rainbow serpents and clouds on top of a Wond'ina head is proved by the interpretation to that effect of a very faint painting in Wolang-Kolong (Pl. III.). All portraits we found of the rainbow serpent emerging from

out the clouds are more or less weather-worn and invariably unrestored (Pl. II. and Figs. 9, 10). Also the representation of the lily blossoms interpreted as clouds in the Brockman gallery at Bind'ibi (Fig. 50) is old and, among our photographs, unique. The condition of all these examples indicates that cloud motifs are no longer in vogue, which adds to the probability that similar paintings which likewise became obsolete had the same significance. Additional finds may perhaps bring more numerous and unambiguous examples in support of the hypothesis here submitted for discussion that the cockatoo feathers do not belong to the older representations, but were painted instead of repainting rainbow serpents and cloud bows.

The devil-devil are mostly fresh; they often seem to be recent additions. Comparison of our photographs with Brockman's reveals an increase of those grotesque little figures over the last decades. Only once was something beyond their name mentioned and their connexion with the Ungud-Wond'ina being referred to: In Kalingi they were described as the attendants of the two serpent women who brought them in from their home, the country of the Unambal, to their husband, Ungud, stated to be Ungarinyin.

Many of the smaller figures are evidence of prevalent sexual conceptions. The figure of a squatting woman with visible genitals recurs in various rock-shelters, largest in Kobuda and well perceptible also in Jandara (Pl. XXIV.). Once acquainted with the motif, one recognizes it in all sorts of sketchy drawings which at first seemed undeterminable. In one case a membrum virile is painted on top of a squatting woman. The penis is much enlarged with the male, the vulva correspondingly accented with the female devil-devil.

In one of Sir George Grey's rediscovered rock-shelters only the Wond'ina paintings with a sexual significance have since been repainted. Referring to the fact, Elkin remarks: " Probably contact with the Mission and the few settlers has lessened the need of painting animals there for increase purposes, that is, to ensure the food supply, but it has not detracted from the importance of the sexual life, its " history " and sanction "*.

Petri holds that the origin of these little figures may to some extent lie in d'anba conceptions and that their increase may be due to the growing influence of the magic Kurangara cults in the Central Australian desert areas. For accented genitals are

*Oceania XIX., 1, p. 8.

typical of all d'anba beings. This hypothesis may be proved or disproved by further investigation. In the former case the devil-devil would turn out to be evidence of a late change of culture in the rock paintings of the Kimberley tribes.

In conclusion I would add a few remarks from the painter's point of view.

The development of contemporaneous art leads us more and more to the understanding of so-called primitive art. Naive art, it might as well—or as badly—be called, since a general characteristic of it is the naivety of its authors. They create their pictures without aesthetic rules, without being aware of the problems of the laws and the object of art. At present it is precisely the art experts who admire their paintings; and it is quite understandable that they would rather not call such art primitive at all. Naive painters rarely depict the environmental world as we view it. They were, therefore, little appreciated some decades ago when the purpose of art was believed to be the rendering of naturalistic reality. To-day what is valued is expressiveness and fine arrangement, which are exactly the qualities of naive works of art.

The more one concentrates on the Wond'ina paintings, the more one feels attracted and interested. One becomes aware of more and more details enhancing the expression or constructive in the composition. To preclude misunderstanding, I wish to emphasize that the following observations are made from the conscious point of view of aesthetic theory which has nothing in common with aboriginal thought.

It is remarkable how ingeniously the paintings are interwoven with the rock formations. Particular figures are accented by means of bulges and projections. Nowhere is there any inconsistency; all representations are so co-ordinated with one another and with the rocks that the effect is organic and magnificent.

Some groups almost call for description in terms of aesthetics. In Kalingi (Pl. XXVI.) the yam tubers ascend slantingly in close procession to the centre which is occupied by the half-length portrait of a lying Wond'ina; the left serpent, above the latter, continues the movement; the right one intercepts it. Moreover, the colours here exhibit a peculiar charm. The agitated confusion of the many serpents, in Maliba I. (Pl. XVIII.), is counterpoised by the vertical configurations on either side, the cockatoos on the left and the broadest of the serpents on the right. The birds seem assimilated to the serpents and yet are clearly marked as birds. At Jandara the group beside the crocodile's head (Pl. XXIV.)

forms a triangle, its sides being the long pointed crocodile's snout and the erect part of the serpent, its basis the two wallabies with the broadest part of the serpent's body. The inside figures are again pressed into triangular shape without impairment to their individual types. The frilled lizards (Pl. XXV.) and the eagle-hawks (Pl. XXX.) fill up flat, rounded niches which called for special concentration in the arrangement of all those figures; more than anything do they appeal to us as self-contained compositions.

I have mentioned such details in terms of our own appreciation of art in order to show that these " primitive " paintings can well be enjoyed and looked at with interest from our point of view. That is one important aspect of the rock paintings. It is possible to appreciate them like any contemporaneous paintings, only that they are then detached from their origin and proper cultural setting. The origin of the Wond'ina paintings, their significance to the aborigines are very different things from the origin and the significance to us of the art of later cultural epochs, although they may be comparable formally.

As was briefly mentioned in the Introduction, the paintings are believed to be evidence of the earthly activities of the mythic heroes who left their shadows behind on the rocks. The aborigines, then, do not regard the paintings as the works of their equals, but as documents of the mythic being represented. Generally, with respect to any of their creations, they only claim to be mediators. The poet of a corroboree is shown a new dance by the spirits of the dead: He only forwards what they have taught him. Even all practical or every-day activities were not originally designed by man. Their hunting practices, the making and use of their weapons and tools have been handed down to the aborigines by the mythic heroes of primeval times. But now they are the conscious makers of their beautiful stone spear-points; they kill their game themselves. What we class as art, the myths and their representation in paintings and dances, is largely a means of getting into communion with the supernatural powers. The change in the attitude of the aborigines during their ritual performances is surprising indeed: There is intense devotion and self-forgetfulness. I remember a myth-teller listening with increasing awe to me repeating one of his stories—one of the deepest lasting impressions I received from the Australian aborigines. I never watched them painting or repainting their picture galleries. Their nature is assurance enough that this too is done in self-forgotten devotion to the object represented, with an undivided zeal. Again in looking at a picture, what engages their mind is the subject-matter and its significance; for

what information they give concerns the objective side. On the other hand, they will give you a fair description of special processes of their handicrafts such as the grinding of colour-pigments.

As far as we can observe, there is no indication that they meditate the formal arrangement of their paintings, though there is some indication to the contrary. Their endeavours " to make 'm pretty fellows " concern such things as careful execution or affectionate embellishment. Expressiveness and fine arrangement spring from an unconscious faculty.

The Wond'ina paintings, then, show that what drives man to represent things is his innate desire for shape and order. The purpose of these paintings is not to copy environmental reality; they are figurations of mythical ideas. It would be out of place to compare them with the models provided by nature. Still, in these " primitive " paintings we find applied certain laws of artistic composition of which we have ourselves become conscious only recently.

The fact is not only important to the anthropologist, but of general interest that in the Kimberleys we are facing the bearers of the culture out of which the rock paintings have grown and obtain from them information about their paintings. For most rock paintings no such direct information is available. Although numerous paintings and engravings have been found in various countries, the answer to the question, what was their import to their authors, can hardly be derived from the paintings themselves. It is doubtful whether further discoveries, however much they may add to our knowledge, can throw more light on this essential point. Rock-painting, over long periods of human history a wide-spread custom, has survived only among a very few peoples. They are the last witnesses of a bygone epoch. It is that epoch from which the earliest evidence of man's image-making activities has come down to us; rock-painting is one of its features. Of course, it is only with due reserve that the Australian hunters of the twentieth century can be compared to the prehistoric painters and sculptors. Still, some information about the Wond'ina paintings may well contribute to the understanding of rock paintings generally.

FIG. 1. A paintress of the expedition, copying rock paintings at Kálingi. The long and high rock wall offers no shade, so large parasols had to be used as a protection against the glare.

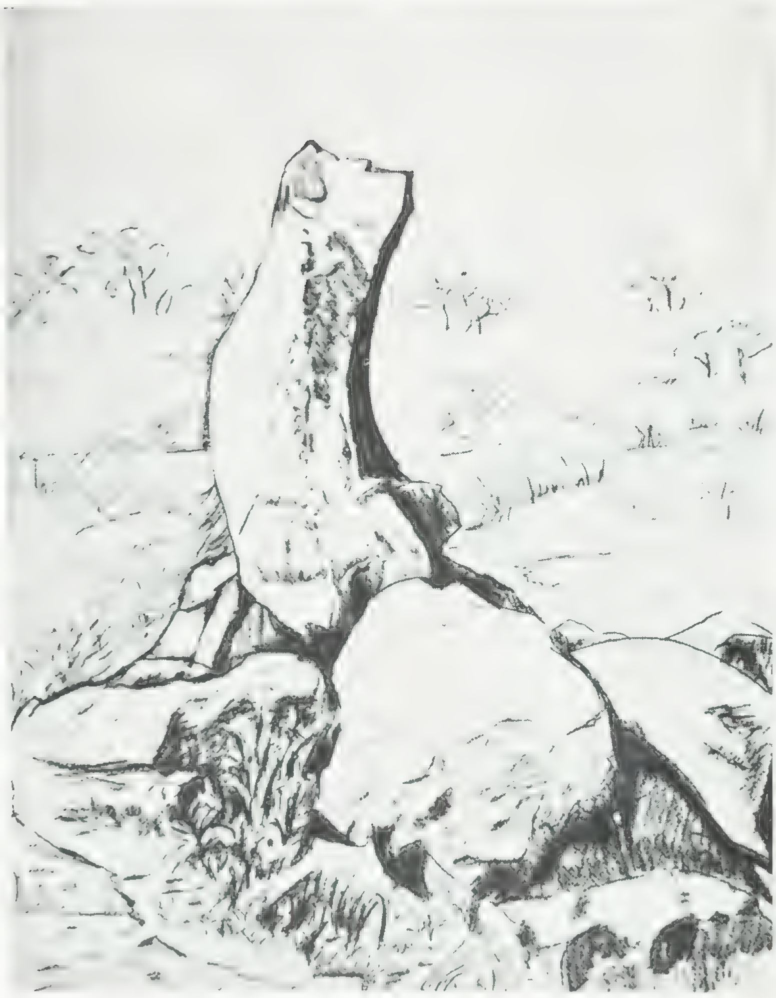


Fig. 2. Menhir-like arrangement of stones on the Korályi-rock, height about 1·40 m.

FIG. 3. Dolmen-like arrangement of stones on the Korályi-rock, width about 1·50 m.

FIG. 4. Korályi. According to the interpretation by old Bronco, the central figure at the bottom is an aquatic being, supposed to be living in Wond'ina billabongs. Length, 85 cm.; colours, red and yellow. The snake on the left-hand side is yellow, with a white head. Above the snake is a nocturnal ghost, red and white, which lives in the grass. The design in the right upper corner represents a variety of yam tuber; painted red and light yellow.

Fig. 5. Korályi. An unexplained animal figure, 58 cm. high, red. The leaflike forms are of a faded red, superimposed over identical designs belonging to an older, yellow painting.

Fig. 6. Ai-ángari. Mulu-Mulú, ca. 1·30 m. high. Light-red ochre, eyes and breast pendant black.

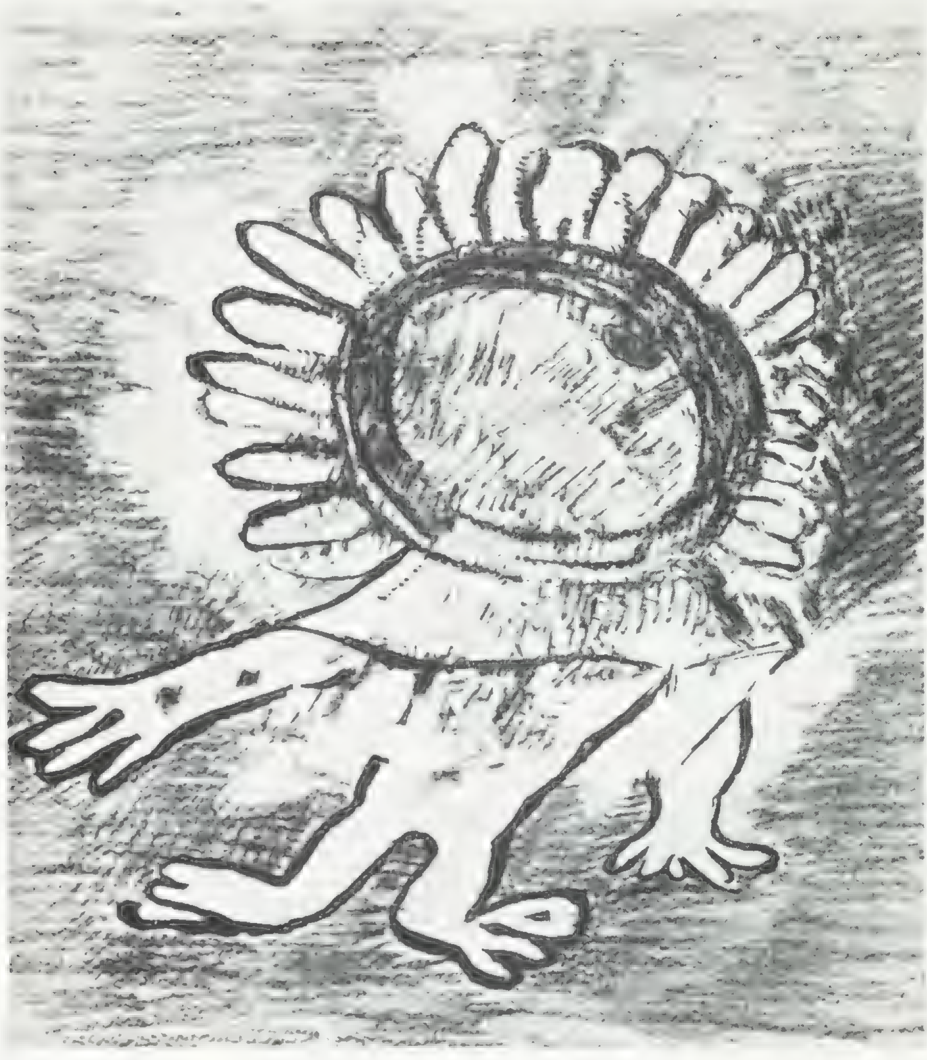


Fig. 7. Wólang-Kolong. Sun, about 50 cm. high; red contours, inside white with yellow circle. Superimposed on an older yellow painting.

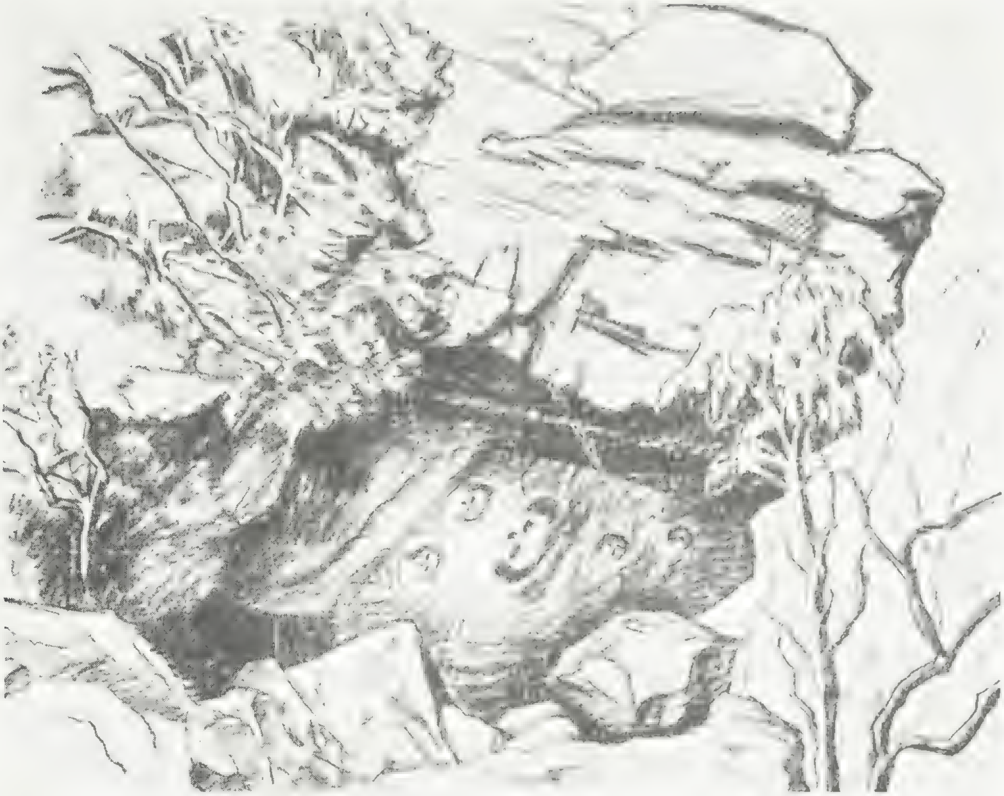


Fig. 8. Módum-shelter with large, lying Wond'ina, 4·20 m. long. Lying on his chest are two small Wond'inas. In front a big piece of rock which is regarded as a rain-cloud. Large rock fragments lying in front of paintings were not unfrequently described in this way.

B

A

Fig. 9a. Bínd-ibi, Frobenius Shelter. A rainbow-snake, light-red and white contours, emerges from clouds red and a little yellow. Width 80 cm. Below a standing Wond'ina, an echidna, and a crocodile. The small white ovals, with strokes across, represent mists which are rising from the ground. These are believed to be produced by the crocodile.

9b. Bínd'ibi, Brockman Shelter. Rainbow-snake, white with red contour, ca. 40 cm. long, emerging from cloud, red and yellow.

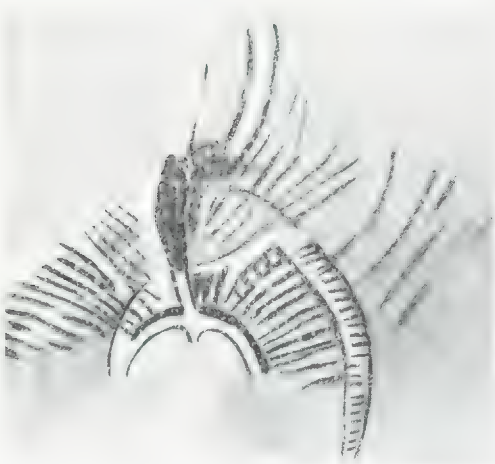


Fig. 10

Fig. 11

Fig. 10. Kerályi. Rainbow-serpent (comp. Plate II); upper part 12 cm. long, black, underneath white with black contour. Emerging from a red cloud.

Fig. 11. Bínd'ibi, Frobenius Shelter. An unexplained motif, approximately 30 to 50 cm. long, presumably imaginary beings, similar to fig. No. 4. The colours are red and yellow.

A B C

Fig. 12a. Bínd'ibi, Frobenius Shelter. Linear figures, squatted, red. Height estimated at 30 to 50 cm.

12b. Korályi. Squatting woman (comp. Plate II), yellow, with brown contour, 28 cm. high.

12c. Wòlang-Kolóng. Squatted linear figures, yellow or red, height estimated at 40 cm.

FIG. 13. Malán A. Above the head of the lying Wond'ina is a tall cockatoo feather, 90 cm. long. On both sides cross-striped snake-like designs, as far as we remember of red colour. Equal and similar figures, more loosely arranged in semi-circles, surround the heads of standing Wond'inas (comp. Plates VII, VIII, and text fig. No. 16*a* and *b*).

FIG. 14. Malán A. Group of animals above the lying Wond'ina: A native companion, 1·60 cm. long, its eggs drawn above the bird. Underneath two tubers beside a bat. On the left a dingo and two small birds which live near the water. Below the red lightning symbol above the arm of the Wond'ina (an important accent in the composition).

FIG. 15. Malán B. Standing Wond'ina 3·55 m. high, beside the tunnel in the middle of the rock. Colours: Red, breast pendant, eyes, dots on the eye-lashes black. the design of the body is unusual. The three small figures above the shoulder have typical Wond'ina characteristics.

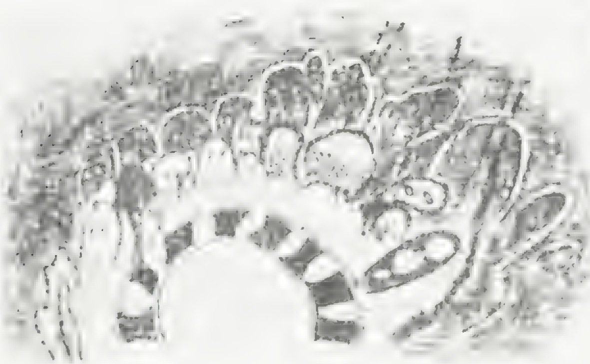


FIG. 16A. Wund'udu-modíngari. Above the repainted ochre bow Wálanganda, width approximately 40 cm., with two cockatoo feathers, two older bows are visible which, however, have not been repainted.

16B. Korályi. The cockatoo feathers (—the upper one 28 cm. long—) of the large lying Wond'ina overlapping an older Wond'ina head with an archaic type of face (comp. fig. No. 49), surrounded by white curvilinear designs interpreted as *ondolon*=clouds.

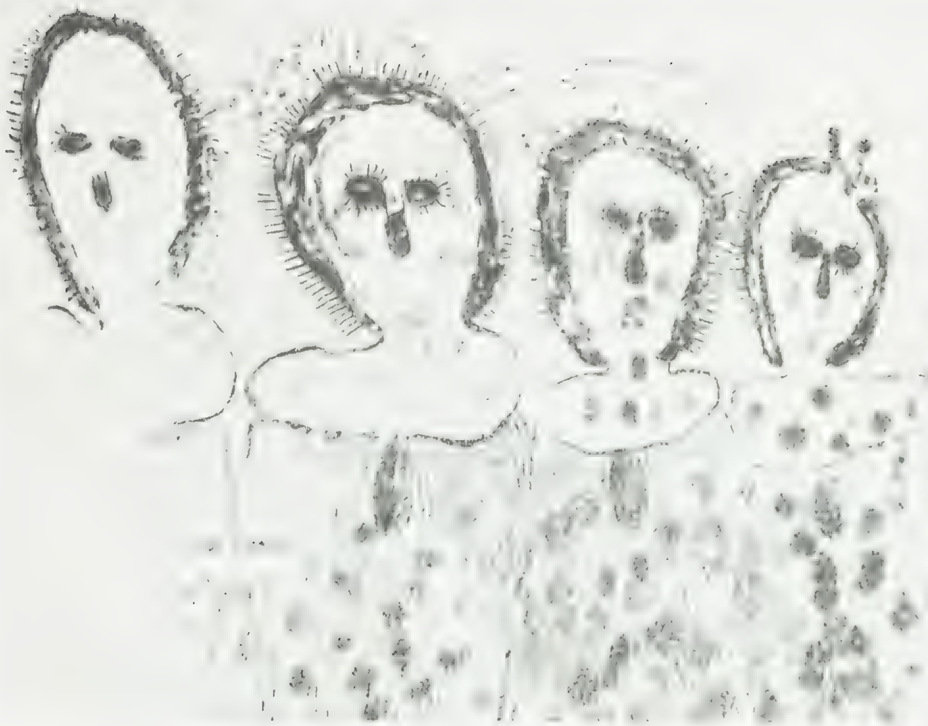
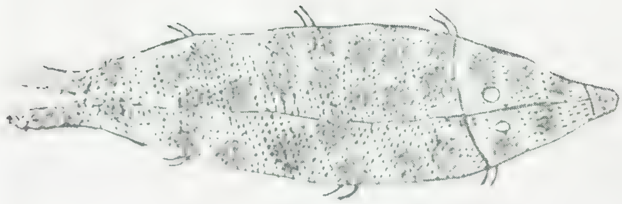


Fig. 17. Amángura. Four Wond'ina semi-figures; height (estimated from memory) ca. 1·50 m.; red; the eyes, noses, and breast pendants black; the thick dots of a lighter red.

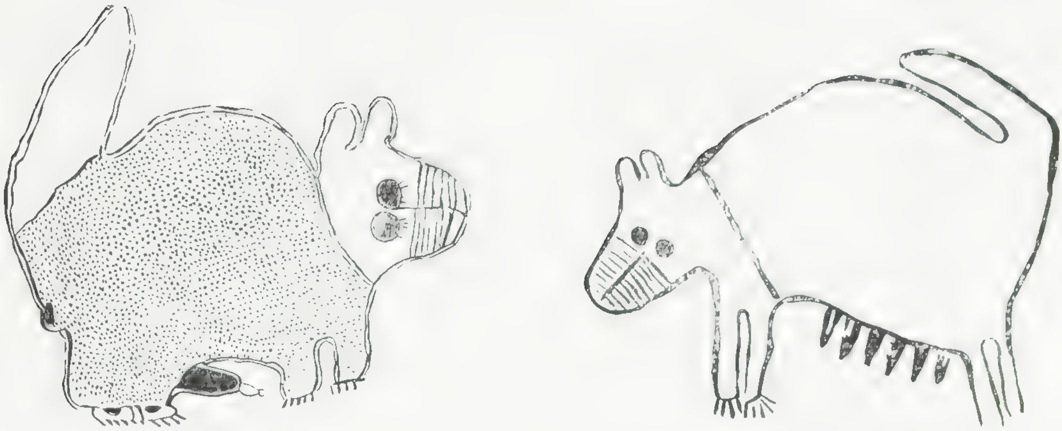


A

B

Fig. 18a. Amángura. Fish (black bream), red. Length (estimated from memory) ca. 40 cm.

18b. Malán. Fish, about 65 cm. long, black contour, design inside body red, the two caudal fins originally painted black, then superimposed red. Lateral fins red.



A B

Fig. 19a. Amángura. Dingo (male). Length (estimated) ca. 1 m. Double contour red and black, dots inside body red; eyes, inner side of hind feet, penis and anus: Black.

19b. Amángura. Dingo (female), length ca. 1 m. Colour red.

A B

Fig. 20a. Kand'álngari. Lambara. (Description from memory): About 30 to 40 cm. long, colour presumably red.

20b. Wólang-Kolóng. Lambara, probably 30 to 40 cm. long and red.

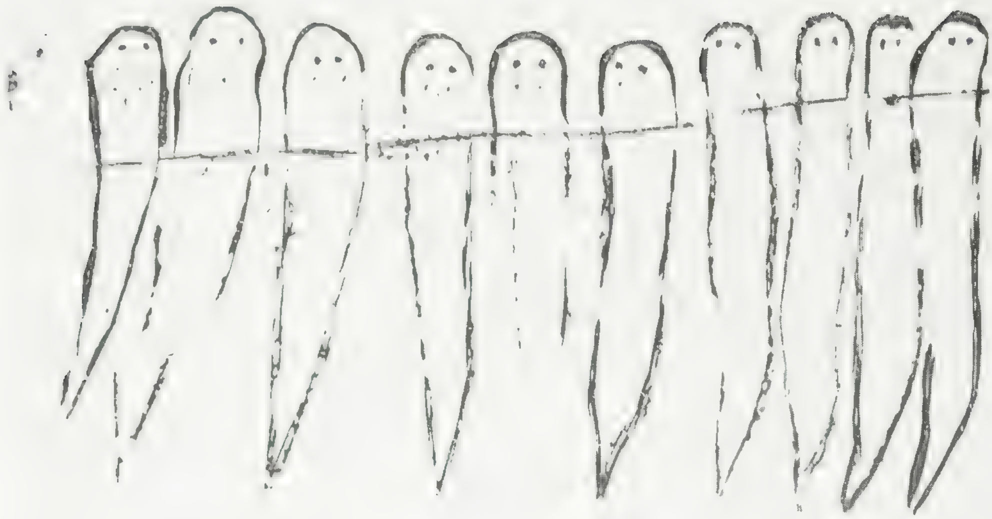


Fig. 21. Jándara. Lámbara? About 20 cm. high; red over an older, black design which is still distinguishable below the superimposed red figures.

Fig. 22. The picture-grotto Máliba II. On the projecting arched rock ceiling five Wond'ina heads. Underneath is a table-like protuberance of the rock.

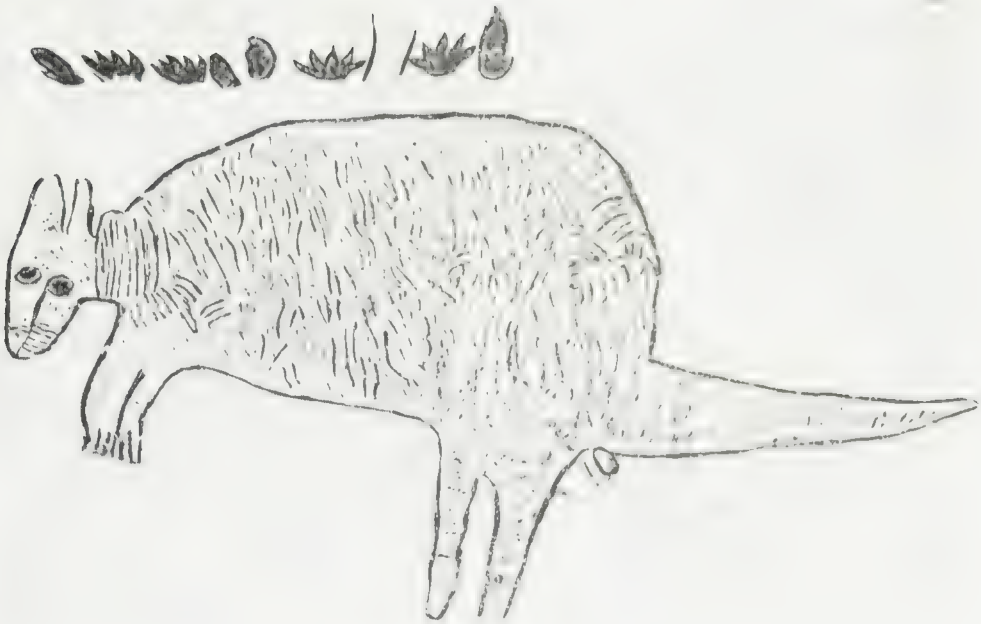
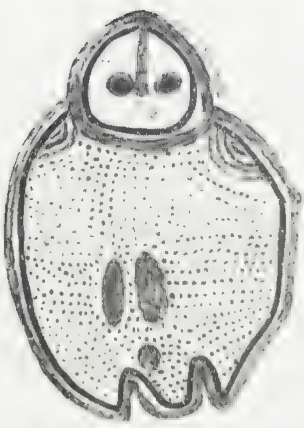


FIG. 23. Bradwodíngari. Kangaroo, approx. 1·50 cm. long (with tail). Colours: Red, eyes and cross-strokes on snout black. Fainter red strokes on the body, representing an older painting superimposed by the white pigment of the latest repaint. The designs above the animal are kangaroo tracks, painted black with red contour; the five-toed tracks being those of the forefeet, the longer (closed) ones those of the hind feet.



A

B

FIG. 24A. Bínd'ibi. Brockman Shelter. Timbi, an owl-like, sacred night bird, 63 cm. high. Red: The broad outer contour, the contours of the eyes and the stroke between the eyes, also the dotted design on the body. The inner contour of the bird and the eyes inside the contours are of a brownish black. The curvilinear designs and the two ovals and circular detail on the body are yellow.

24B. Maliba (I). Some more sketchy representations of the *timbi*, 25 cm. high, red. Inside the largest specimen on the right there are faint strokes painted a brownish yellow. The figure of the snake rising from the left lower corner was painted between the ancient yellow and the latest (red) layer.

FIG. 25A. Máliba I. Lizard, 30 cm. high, yellow, partly covered with superimposed white paint, partly peeled off.

25B. Long-necked tortoise, height 27 cm., yellow (like (*a*)).

25C. Tortoise, height 25 cm., painted red over an older, brownish-yellow design of the same animal, of which the dots are still visible. The circles inside the body represent the eggs.

FIG. 26. The picture-grotto Jándara, situated on the border of a sandstone elevation. The rock, which is grown in slate-like layers, is projecting particularly far in one place forming shelters with perfectly horizontal and smooth ceilings. On the largest of these ceilings, the crocodile reproduced on Plate XXIII*a*., 4·35 m. long, is painted. In the background Plate XXIII*b*. In the left lower corner the bones mentioned on p. 39, originally wrapped in paper bark.

Fig. 27. Jándara. Crocodile, 48 cm. high, red. The wavy lines on the right are a natural formation of the Jándara sandstone, giving the impression of rippled water, a particular attraction of the picture.

Fig. 28. Kóbuda. Head of the Ant-Wond'ina (Plate XXVI.), width of eyes 42 cm. Red, contour of eyes black.

Fig. 29a. Kóbuda. Weathered Wond'ina head, 23 cm. wide. From the centre of its ochre bow, a broad red line (lightning symbol?) emerges, framing a number of very faded, serpent-like black figures (lámbara? Comp. Nos. 20 and 21). Above is a snake. Superimposed over the serpentine figures is a more recent drawing of a wallaby with a young in its pouch. Faint traces of a more ancient picture indicate that the wallaby was formerly drawn farther down.

29b. Wallaby group beside the more ancient picture of a serpent, red; the large wallaby—length from the hind feet to the hump 40 cm.—has been largely repainted, while the young in the pouch and the small wallaby in front are older paintings. The upper cross-lines on the tail of the large wallaby belong to the older painting.

Fig. 30. Tēgulan-odin (Nalár). Frilled lizard approx. 90 cm. long, and a large yam tuber. Colour red.

Fig. 31. Anúmeri II. Two representations from Káluru. (*a*) Wond'ina head, 40 cm. wide, light red: Ochre bow, contours of eyes and nose. Dark grey: Spaces of the eyes, dots round the eyes, inner contour and dots outside and parallel to the ochre bow. The rest of the picture is a light-grey outline drawing of problematic significance. (*b*) Wond'ina head, 30 cm. wide, monochrome painting in a greyish-violet shade—a rare colour. Partly overlapping are light-grey lines which have not been interpreted.

FIG. 32. Lánganana. Presumably *mai-ángari* for yams, length 28 cm.; and the sun. Red, a little white, and yellow spots.

FIG. 33. Anúmeri I. Elongated figure, 29 cm. high; yams, and a crocodile, brown-red. The little men brownish-black.

FIG. 34. Lánganana. Outline of a large figure, with tuft of hair (?), length 35 cm.; and six smaller companions. Colour a reddish-brown. Was explained as " d'imi with children " or as " father of the Drysdale Mission taking native children for a walk ". Representation of walking persons in an horizontal position is an example of totally different kind of vision.

FIG. 35. Lánganana. Three human figures, the tallest on the left side is 15 cm. high; a light reddish-brown.

Fig. 36. Kanbudjoa dangi II. Woman, 25 cm. high, with large breasts, suckling child. On left a small figure with clumsy head, carrying a basket in one hand. On the right an older, faded figure. The figures are painted in a dark red-brown, except the faded figure which is light-brown.

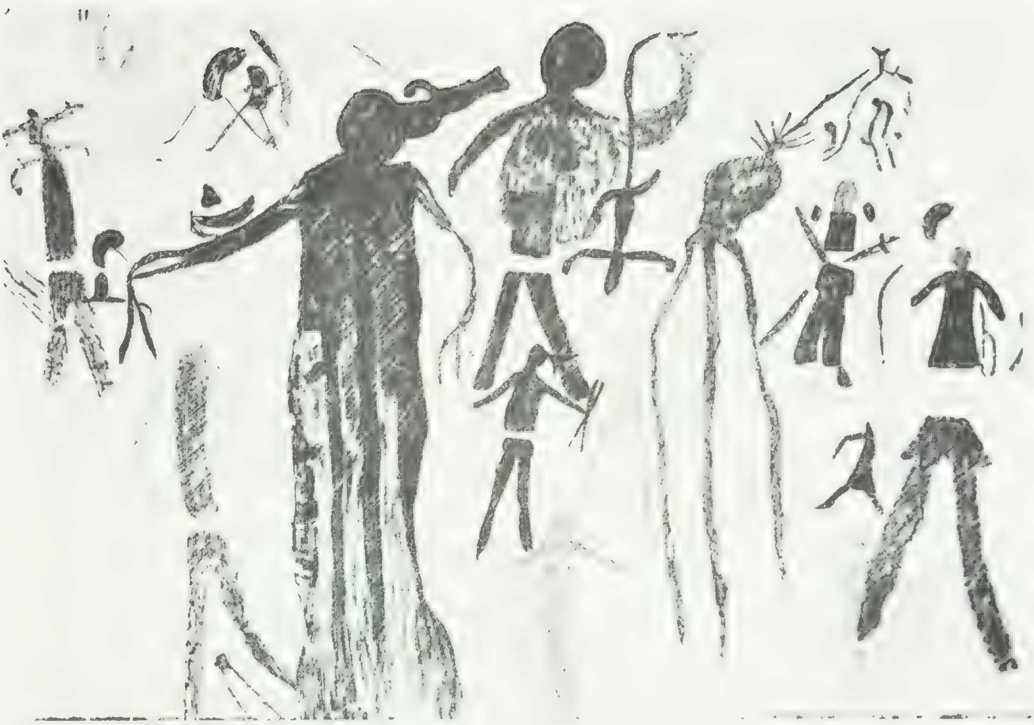


Fig. 37. Kanbadjoadangi I. Human figures, partly dressed, the largest 65 cm. high. There are layers of paintings of different age; on the other hand, we noticed that, on the same figure the pigment was sometimes applied in various degrees of thickness. The youngest stratum is represented by the following figures, viz.: The little man in the centre wearing a belt, his head-dress painted over the leg of the larger figure above. The man is probably carrying two wadis (clubs). Colour: Brown. Also the black superimposed garments of two small figures on the right. The oldest stratum: The faded red traces of walking figures. The rest is, partly, dark-brown, partly a lighter red-brown; the lizard, with long tail is somewhat mauve. The figure on the right of the lizard is presumably a tuber with three roots.

Fig. 38. Anúmeri I. Human figure with spread-out legs, height 27 cm. Colour brown.

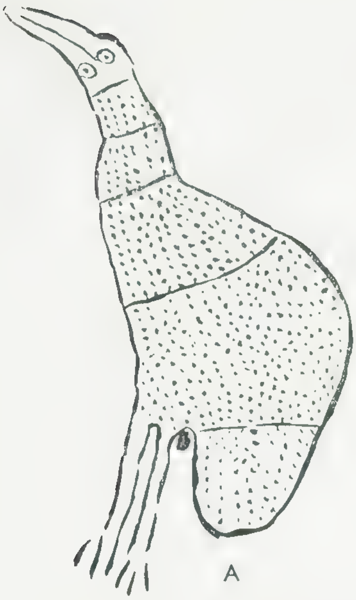
Fig. 39. Kanbudjoadangi II. Two squatted figures, 8 cm. high, faded brown. The figure on the right apparently holding something similar to a branch.

FIG. 40 (A and B). Near Malán. Faded figures, the tallest ca. 55 cm. high. Faint grey-violet.

FIG. 41. Kóbuda. Traces of ancient paintings. The outstretched arms of the small figure in the upper centre about 16 cm. wide, colour a faded brown-red.

Fig. 42. Módum. Painting without a white ground, on the left side of the picture grotto proper. Height 44 cm., a brownish colour.
43. Mánojina near Drysdale. Unexplained motif. No data.

Fig. 44. Bínd'ibi, Brockman Shelter. A row of figures interpreted as frogs, the tallest on the left 22 cm. high. Colour: Red, but the eyes and also some of the lower parts of the figures black. There is no white ground, but the figures are framed by white outlines.



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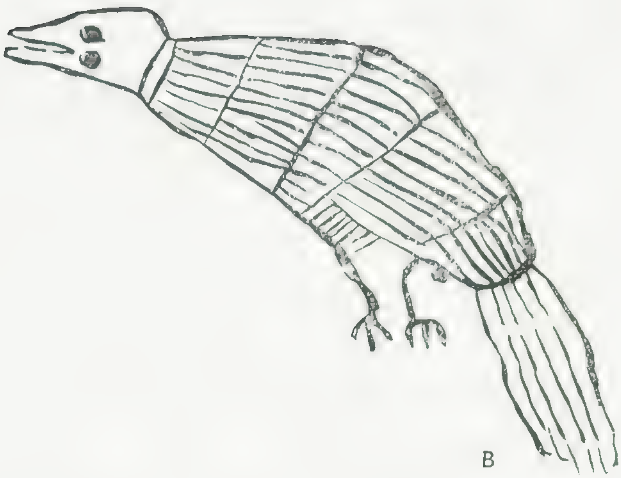
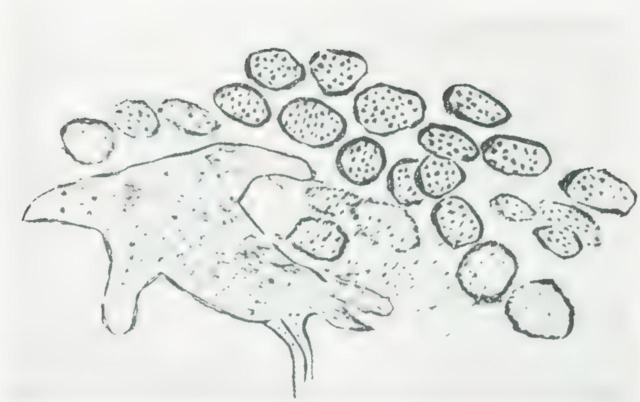


B

FIG. 45A. A bird from the Brockman Shelter, Bínd'ibi, ca. 44 cm. high, red.
45B. A bird from Ai. ángari, approximately 35 to 45 cm. high, red.

FIG. 46. Amángura. Drawing interpreted as a phalanger, but presumably representation of a bird. Estimated height 50 cm.; red.

A



B

Fig. 47a. Jándara. Two birds, the upper 33 cm. high, red. Yellow stripes consisting of dotted lines belong to an older picture underneath.

47b. Yangálu. A bird, which lives near the water; from head to tail ca. 40 cm. The round patterns with dots are tubers. Colour red.

Fig. 48. Bínd'ibi, Brockman Shelter. Two echidnas beside a more recent Wond'ina head (width of the latter ca. 30 cm). The echidna figures are old and have not been repainted for a long time. The latest layer is red, the pigment has peeled off in many places, revealing an older, yellow, painting of the same animals.

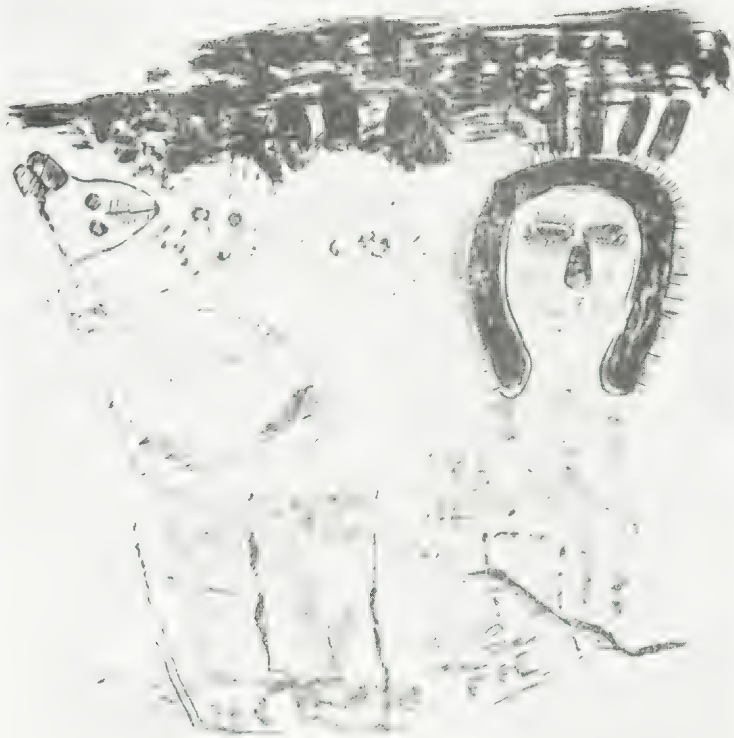


FIG. 49. Bínd'ibi. Brockman Shelter. Two very ancient Wond'ina faces beside a repainted Wond'ina head on the right, width 40 cm. In the left upper corner is a wallaby head which is older than the repainted Wond'ina head but looks fresher than the two old faces. Three pairs of legs, presumably traces of standing figures. These legs are covered with little red strokes (vertical on the legs, but horizontal on the feet; this is not recognizable in the photograph). Beside the cockatoo feathers belonging to the repainted Wond'ina head, there are other repainted cockatoo feathers.

FIG. 50. Bínd'ibi, Brockman Shelter. Two representations of lily blossoms, the one on the right 11 cm. high. These blossoms are supposed to be identical with clouds. Between them a cloud design interpreted as mist rising from the ground (comp. text ill. No. 9*a*). The blossoms are white with red contours, on the left is a superimposed black outline. Clouds of mist white, the lower one has a little black pigment inside. There are some old red, yellow, and black spots which may be traces of older, faded designs, of blossoms.

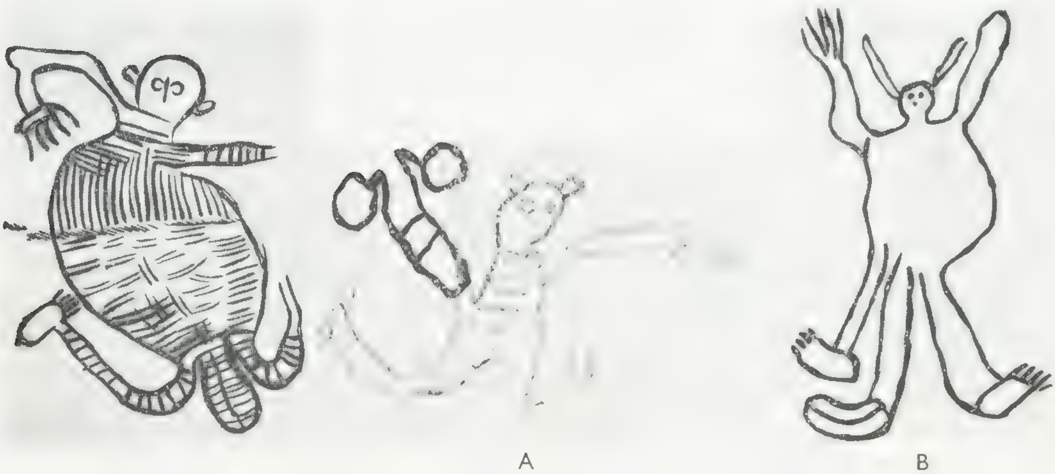


FIG. 51. Jándara. Fresh drawing of a squatted woman, dark-yellow, 54 cm. high.

51A. Kálingi. " Devil-devil " over the serpent-women, Plate XV*b*.

(*a*) Squatted woman yellow, membrum virile black.

(*b*) 9 cm. high; black.

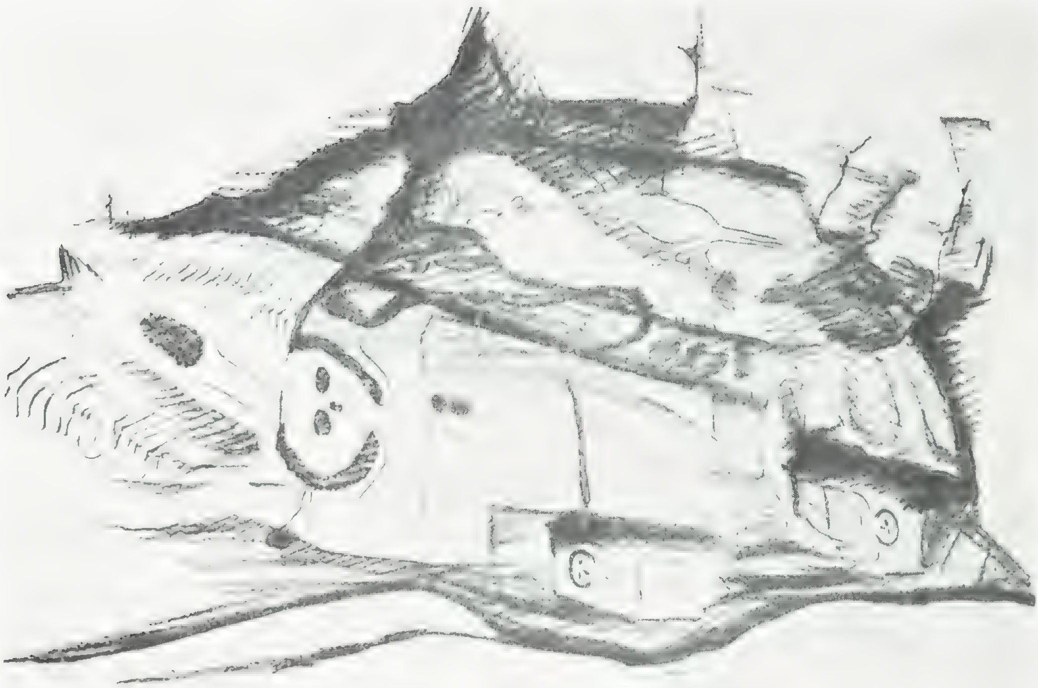


Fig. 52. Malán. Illustration of the imaginative composition of the figures in connexion with the natural structure of the rock wall (Plate VI., right hand side).

A

B

Plate Ia.—Korályi. (Photograph by Fox.)

Lying Wond'ina, 5·90 m. long. His body is covered with Wond'ina heads. The colours are the most common, viz.: Red ochre bow, cockatoo feathers red and black, lightning symbol yellow, eyes black, nose red, eyelashes and hair red with black dots; the black hands and feet with red contours are rather unusual.

Plate Ib.—Ai-ángari. (Photograph by Fox.)

Lying Wond'ina, at least 3 m. long, light-red ochre bow, the eyes, contours of the lying figure, and tips of toes black.

Plate II. Korályi. (Watercolour by Kleist-Schulz.)

Lying mulu-mulú—female Wond'ina—with stripes across its length. 97 cm. long, red, on the feet old, very faded stripes, black. A red rectangular design presumably represents a bucket of tree bark. Squatted figure above yellow, contours and vulva brown. Above the head white rainbow-snake with red outline emerging from a red cloud. Above the feet of the mulu-mulú a rainbow-snake which is mainly black, its smaller, lower portion white with black contour. A cloud with red lines. Superimposed on a older, larger design of the same motif, in the same colours. On the left a faded Wond'ina head, red, older type with round eyes and round nose, inside black with red eye-lashes and contours. White bows above interpreted as " nebulous clouds ". Three bats, black bodies with rows of white dots, black eyes; head, neck, outline, and legs red. Three repainted Wond'ina heads like Plate I.—Right lower corner: An old yam design, yellow.

Plate III.—Wólang-Kolóng. (Photograph by Fox.)

Paintings about 7 m. long. All the ochre bows and contours also hair-belt and hand of the large lying Wond'ina: Red. Eyes: Black; head of the long-necked tortoise (on the left): Yellowish-white.

Plate IVa. Bínd'ibi, Frobenius Rock Shelter. (Photograph by Schulz.)

Lying Wond'ina, 5·85 m. long, two small Wond'inas, and a Wond'ina head. The head with cockatoo feathers as well as the contours of the body, the design inside, the hair belt, hands and feet are almost entirely painted red; only the eye-lashes round the black eyes, and the noses, are yellow. In the right lower corner a yellow lightning symbol.

Plate IVb. Bind'ibi, Frobenius Rock Shelter. (Photograph by Schulz.)

Paintings about 12 m. long. On the left, an old long-necked tortoise, ca. 1 m. long, faint-pink, white and yellowish contour, without white ground and without any trace of repainting. Kangaroo, length (with tail) 1.30 m., red outline, eyes and design inside contours of head: Black. Some ancient, obliterated dots on the surface of the body were probably black. Standing Wond'ina, see Plate V. On the right a rainbow snake and smaller standing Wond'ina (see No. 9a).

PLATE V. Bínd'ibi, Frobenius Rock Shelter. (Watercolour by Kleist.)

Standing Wond'ina, height (with the hair) 90 cm. The contours and the ochre bow repainted reddish-brown. The following details are older, painted a dull greyish-brown: The hair, sticking out; the design on the surface of the body. The eyes and nose and (hardly recognizable) a breast-shield(?) also belong to an older layer but show a more reddish shade.

Plate VI. Malán. (Photograph by Schulz.)

Lying Wond'ina, 3 m. long, the two small ones 1 m. and 1·08 m. Painted mainly in red. For the animal group on top of the large Wond'ina see No. 14. Standing Wond'ina on the left 3·55 m. high (see No. 15). The painting is on the left hand side of a low tunnel leading through the rock to the other side.

Plate VII. Malán. (After a photograph by Schulz.)

Standing Wond'ina's at the south-west corner. The one which has been repainted is 1·10 m. high. Eyes and nose are black with red contours, the eye lashes are red with black dots. The ancient frame of the head, which was never found repainted, can be fairly clearly distinguished in this picture.

PLATE VIII. Yangálu. (Photograph by Schulz.)

The name means "rain-cloud", the whole rock, lying as it is in complete isolation, is conceived as such. In the centre, there is a roomy passage. Underneath the darkest shadow we can see the sunny scenery on the other side, while the paintings are visible in the left. The faded large red ochre bow, 1 m. wide, is surrounded by radial serpentine figures. Six of these, with stripes across and with two eyes, are on the right of vertically rising lightning symbols, painted twice red-white-red. These did not come out very well in the photograph but were fairly distinct in the original.

Plate IX. Yangalu. (Photograph by Schulz.)

Standing Wond'ina, 1·77 m. high. Design red, cockatoo feathers black-red-black, fingers black. Above the red stripes of the large Wond'ina bust with faded head (Plate VIII.).

Plate X. Wund'udu-modíngari. (Photograph by Fox.)

Wund'udu or Walangand, the celestial hero of the Ungarinyin, visible as the Milky Way, Height approximately 1·80 m., and two Wond'ina half-figures. Yellow ochre has been used instead of the usual red ochre. Eyes, breast-shield, inner contour of face and breast are black. Ancient arcs round the heads have not been repainted. Comp. Plate VII.

PLATE XI. Kand'alngari. (Photograph by Fox.)

A row of Wond'ina heads painted below some light quartz veins in the rock in the shape of a lightning symbol. Ochre bows light-red as at Ai-ángari (a shade peculiar to this district). The eyes are black.

Plate XII. Máliba (II.). (Watercolour by Kleist.)

A group of Wond'ina heads, the largest is (with the hair) 32 cm. wide. Colours red and white except black inner spaces of the eyes; on the older head in the right upper corner, there is a black line inside the ochre bow. Black dots on eye-lashes and hair. Half of the nose is black (an older stratum?).

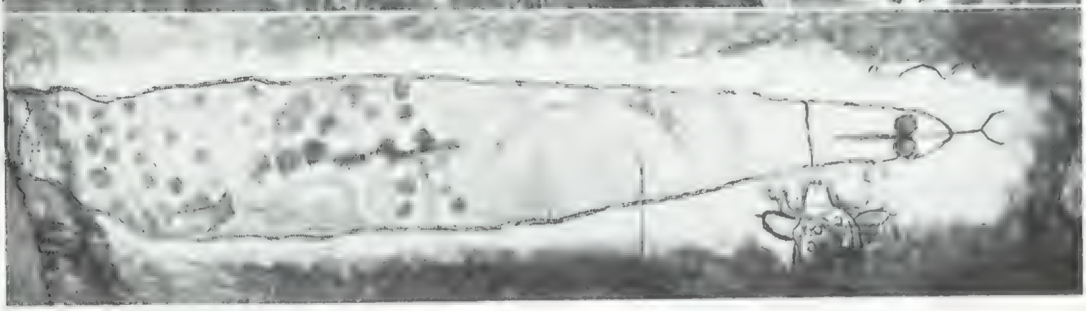
PLATE XIII. Brad-wodíngari. (Photograph by Fox.)

Brad, the rising sun. The central line (nose to tip of cockatoo feather) 75 cm. long. Principal colour; Light-yellow ochre, accentuated by narrow black intersecting lines. Black inner spaces of eyes, nose, and tip of feather, and black dots at eye-lashes.

Plate XIV. Kálingi-ōdin. (Photograph by Fox.)

The upright *Ungud*-snake is 3·15 m. high (not including the tongue). On the left side the serpent-wives of Ungud, on the right the Wond'ina Nyandugarali.

A



B

Plate XVa. Ungud Kálingi. (Watercolour by Schulz.)

Height 3·15 m. The inner contour of eyes and trunk and the eyes of the small half figure on the right are black. Red details: Outer contours and small dots somewhat underneath the line running across; also a vertical stroke above the eyes and tongue and the outlines of the little figures right and left. The following details are yellow: Thick dots below, small dots round the cross line, upper line across and outer contour of head; the inner spaces of the eyes and the broad vertical stroke below the eyes.

Plate XVb. Kálingi. (Watercolour by Schulz.)

Serpent-wives of Ungud 3·12 m. long. Red: Outer contours, tongues and strokes inside the heads, little dots and strokes inside the bodies of the snakes; small figures. Black: Outer contours, Wond'ina eyes, membrum virile. Yellow: Thick dots inside the snake bodies, spaces of the eyes, and figure above the heads of the serpents.

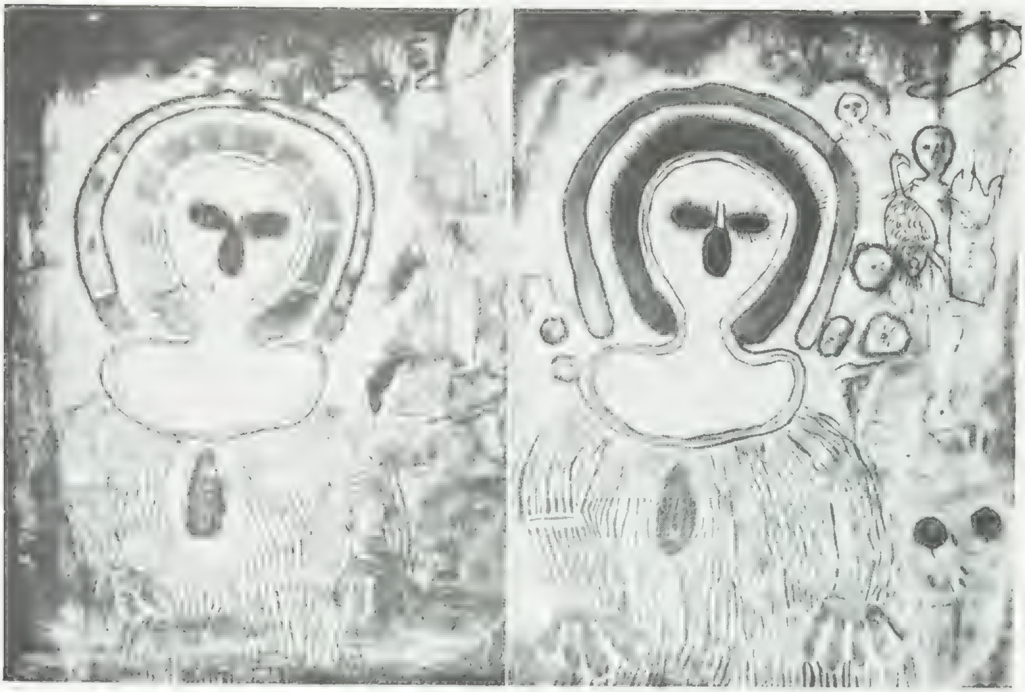


Plate XVI. Kálingi. (*a*) Photograph by Rockman (Museum in Perth, W.A.,). (*b*) Watercolour by Schulz.

Wond'ina Nyàndugaiali, Height 1·80 m. (*a*) (left side), The photograph taken by Brockman in 1901; (*b*) (right side), copied during the Frobenius Expedition, 1938. Colours: Red: The ochre bow, outline of lightning symbol, contours of eyes and nose, eye-lashes and hair, outer and inner contours of neck and shoulder; and small secondary designs. The nose is brown through red superimposed on black underpaint. Black: Spaces of eyes, the dots on eye-lashes and hair, the cental line of the threefold contour; furthermore the breast-shield and the hands. Yellow: Inner space of the lightning symbol.

PLATE XVII. Kálingi. (Watercolour by Schulz.)

Yam tubers, the longest 90 cm.; and Wond'ina heads. Ochre bows a light brownish-red. Lightning symbol of the lying Wond'ina is yellow, with brown contour; those of the two lower ones crimson-red; that of the smaller one above the one on the left is brown. The eyes are black, the noses partly black and, partly, brownish-red. The yam tubers and the shorter standing Wond'ina are red. Of the two serpents in the centre of the upper half of the painting the left one is yellow with a white head, the right one a dark reddish-brown with yellow contour; tongue and four protuberances on the head are yellow with reddish-brown contours.

Plate XVIII. Máliba (I.). (Watercolour by Kleist.)

Ten Ungud-snakes, the one on the extreme right 55 cm. long (including the tongue). Tongues red, contours red. Nine serpents have a second contour which is yellow. The eyes are mostly yellow inside, red outside, while the cockatoos and small snakes show the reverse colour arrangement. The dots on the bodies of the serpents are, at the bottom, mostly yellow; some rows are red, at the top mostly black, but, partly, very faded. On the left two cockatoos with yellow dotted patterns and each with two stripes across the breast, the upper red, the lower bluish-grey (produced by a mixture of black and white).

Plate XIX. Máliba (I.). (Photograph by Schulz.)
This is the same group as reproduced on Plate XVIII., but somewhat foreshortened.

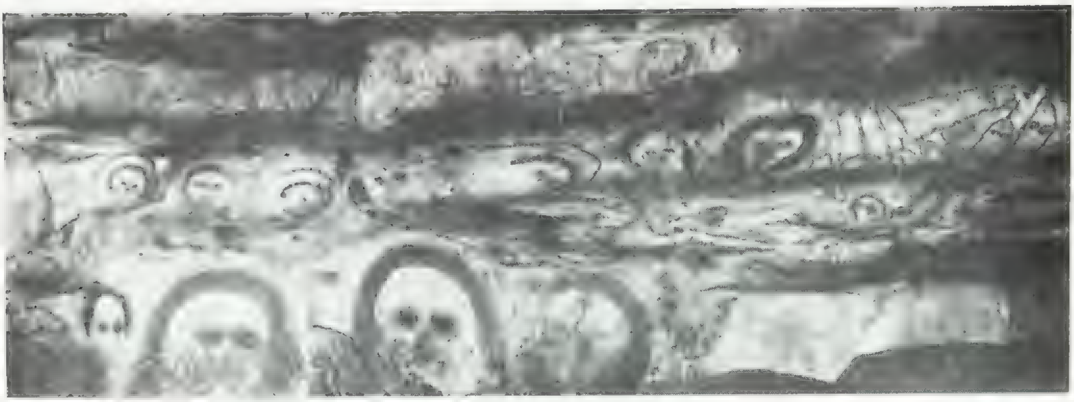


Plate XX. Máliba. (Photograph by Schulz.)

Paintings on the left of the Ungud-serpents (Plates XVII. and XVIII.). Particularly remarkable are the three small Wond'ina heads with narrow reduplications of the ochre bows, painted on bulges on the rock wall, thus producing a plastic effect. In the colouring of the central head, yellow is predominant, as in the lightning symbol, the hair surounding the red ochre bow, the nose, the inner (black rimmed) spaces of the eyes, and the dots which are framing the eyes instead of eye-lashes. On the left an ancient drawing of lizards (No. 25a); yellow, right on top of the yellow lightning-design of the left, lower, large Wond'ina head. The lowest Wond'ina heads, as usual, red with black eyes and black dots on eye-lashes and hair. In the lightning-design above the lower Wond'ina head on the right, contour and ends are red (over yellow), while the dots on the inside were left yellow. Above a yellow long-necked tortoise, partly peeled off (No. 25b). Next to it is one of the three small "plastic" Wond'ina heads. Obliquely underneath three red *timbi* (No. 24), here seen in foreshortening. The other Wond'ina heads show the usual colouring. The kangaroo figure below is red. So is the little figure on the extreme left, like a similar figure in the Frobenius rock shelter, likewise in the left corner of the paintings (p. 17, Plate Vb).

Plate XXI. Mangángu. (Watercolour by Kleist.)

The evil serpent Nonurungun, with its abdomen full of many devoured human beings, painted on two bulges of the rock. Colours: Red: The broad outline, tongue, dotted and stroke design on the body; Black: The eyes, thin contour of the tongue, head and upper part, the small figure inside the head. Yellow: Outline of the eyes, outermost contour of head. The little fish is red, the eyes, stroke and dots inside the head are black. Two bats have black bodies with thick white dots, red contours, and stripes across the neck.

Plate XXII. Máunginga. (Photograph by Fox.)

Black head-snake-Ungud, Wond'inas, and tubers. The Wond'ina bust in the centre approximately 0·80-1 m. high (estimated from memory). Red: head of serpent, eyes, breast shields: black.

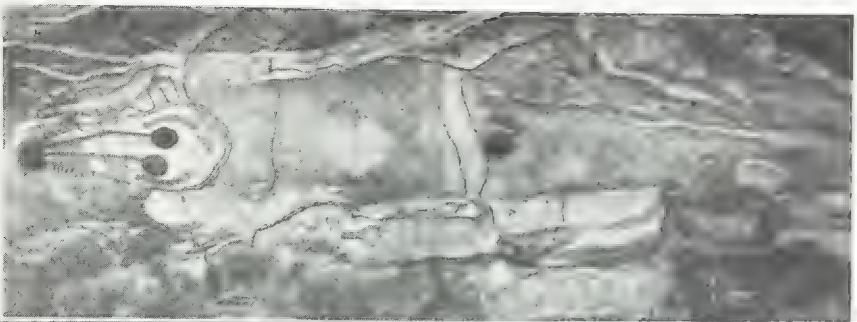


Plate XXIIIa. Jándara. (Watercolour by Schulz.)

The crocodile-Wond'ina in his zoomorphic form. Contours of the body: Red and black. Dotted and stroke design on surfaces of the body: Red. Outline of head: Yellow and black; eyes and snout with black and yellow border. Cross-lines on the snout: Red. Two lines from the eyes to the snout: Centre red, sides yellow. Fivefold bows beside the eyes: Yellow. Small figure on the head: Black. Small crocodile and figure below: Red.

Plate XXIIIb. Jándara. (Photograph by Schulz.)

Two lying Wond'inas, but only the one on the left side still recognizable as a figure. Length 1·30 m., red, eyes black inside. On the right two red borders (No. 47a), the upper superimposed over yellow and red stripes of unclear significance, the lower over a layer of white through which the design of the body of the lying Wond'ina on the right is very faintly visible.

Plate XXIV. Jándara. (Watercolour by Kleist.)

Group of figures beside the snout of the crocodile-Wond'ina (right upper corner). Squatted woman, ca. 45 cm. high, red. Native companion, yellow; superimposed is a rough red outline. The yellow design of the head and upper portion of the body of the bird is drawn over an identical older design in black, but the latter is not completely covered. The original contour of the coiled snake was black, but a red contour has been superimposed. Where both lines—the red over the black—are completely congruent with each other, the colour effect is a brownish red. Design on the body partly black, partly a light-red, and, partly, dark-red, the latter shade produced by red superimposed on black. The head of the snake reveals two different designs; the larger head with tongue is light-red, the red eyes with yellow contours belong to this head. Two figures of fish in the left lower corner are done in red, inaccurately superimposed over older, black contours. The two wallabies are red, older black outlines can be distinguished.

Plate XXV. Tégulan (Premun'anban). (Photograph by Fox.)

Frilled lizards, the largest semi-figure somewhat similar to the anthropomorphous Wond'ina type. Length of the animal below (estimated from memory) ca. 1 m. The double contours black.

PLATE XXVI. Kóbuda. (Photograph by Schulz.)

View of the left side of the rock shelter with painting of the head of the ant-Wond'ina (see No. 28).

PLATE XXVII. Kóbuda. (Watercolour by Schulz.)

Squatted woman, ca. 44 cm. high, light-red. An older, black, design is not always covered. The large bow and the design on top of the head are red; the horizontal lines above are faded black. The attribute on the right, below the left arm of the woman, is unclear.

Plate XXVIII. Kóbuda. (Polychrome drawing by Schulz.)

Standing Wond'ina, 76 cm. high, with kangaroo and wallabies. Drawing is red, only the eyes of the Wond'ina and the outline of the large serpent appearing over the fissure in the rock are black. The lightning symbol with its ramifications emerges from the shoulder of the Wond'ina. The style of the more recent designs differs from the conventional by the attempts of rendering movement. A very ancient representation of a long-necked tortoise on the left and presumably that of another below the kangaroo, with long cross-striped neck upwards to the right. Ordinary tortoise more distinct and thus apparently more recent; its state of preservation approximately the same as that of the very tiny figure of a Wond'ina.

Plate XXIX. Tégulan (Nalar). Photograph by Fox.)

Two frilled lizards, 92 cm. high, an dyam tubers. Colour red, except the eyes and outer contours of the lizards (black), and the upper, painted, parts of the yams (yellow).

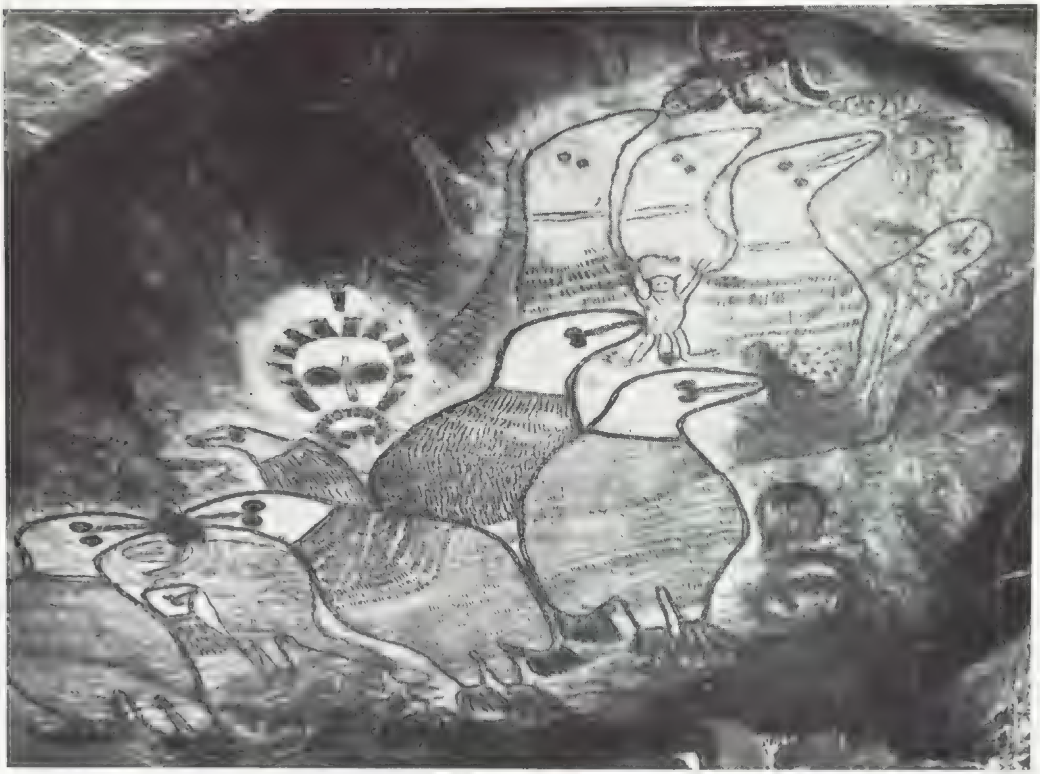


Plate XXX. Warána. (Photograph by Fox.)

Lower portion of picture: Group of four large eagle-hawks, two smaller (incomplete) ones, and wallaby: Black and red contours, black eyes, red-rimmed. On the bodies of the four large birds red strokes and black dots. Wond'ina heads: Red with black eyes and dots on eye-lashes and hair. Three heads of eagle-hawks above: Red, eyes black. The small figures red and black, the striped figure above the Wond'ina yellow.

Plate XXXIa. Longónye. (Photograph by Petri.)

Ca. 6-8 miles north-west of the new Drysdale River Mission Station and the King Edward river. The river plain is enclosed, on both sides, by a raised sandstone formation. On the border of these, there are isolated rocks, much crumbled away through weathering. The figures painted on those rocks are about 50 cm. high (estimated from memory), in lively movement, apparently dancing. On the right a very unclear figure is faded reddish-brown.

PLATE XXXIB. Wóliba, in the neighbourhood of Longónye. (Photograph by Petri.)

In the centre a fragment, apparently a squatted figure. On both sides elongated figures, about 1 m. high (estimated from memory). The figure on the left is flanked, on either side, by a shorter figure, overcrowned by threefold semicircles. The figure on the right is overlapped, in the middle, by a semicircle. On the right of this figure there was probably a very small figure. Faded reddish-brown.

Plate XXXIIa. Wóliba. (Photograph by Petri.)

A curious figure, approximately 80 cm. high (estimated from memory). Shape of the head similar to the figure shown on Plate XXXIII. The meaning of the protuberances on neck and thigh is problematic. Faded reddish-brown.

Plate XXXIIb. Kanbudjoadangi (IIi). Photograph by Fox.)

On the high rock wall above the shelter two figures, the left one ca. 65 m. high. Contours dark violet-brown; the surface of the left figure a lighter reddish-brown. The design of the arms and the strings dangling down from the belt resemble the corresponding details on the bent figure at Malan, Plate XXXIV.

Plate XXXIII. Anúmeri (I.).

In the centre, painted over the fragments of ancient figures, a distinct running figure, measuring about 35 cm. from foot to foot. In front of it faded remnants of a similar running figure; underneath the dots apparently several lying figures, and below again a running one. In the centre below presumably a standing figure; superimposed are the contours of a figure with a spear. The disinctly running figure and the spearman show the same peculiar shape of the head. More ancient paintings on the right are not recognizable, above is a clumsy figure without arms. Apparently the dots and a snake consisting of rows of little dots were painted later than the ancient fragments, but earlier than the running figure. As far as the age of vegetable (?) motives between the snake and the dots is concerned, it is only certain that they originated before the running figure which is superimposed on them; it is probable that they belong to the oldest fragments. Different shades of reddish-brown.

Plate XXXIV. Malán.

Bent figure, about 63 cm. high; reddish-brown. The designs in front of the figure are unexplained. They are of a somewhat more violet shade, and streaky colour pigment is distinct in various places. Water seems to have trickled over these designs.

Plate XXXVa. Malán.

Elongated figure with outstretched arms, height about 1 m.; reddish-brown. On the right, painted over the arm are presumably vegetable motives, the inner group of three branch-like forms has three yellow points. Amongst a variety of unrecognizable patches of pigment we find, on the left, a small faded replica of the somewhat lighter long brown-red figure with outstretched arms. The meaning of the design on the right is problematic.

Plate XXXVb. Malán.

The most distinct figure, about 90 cm. high, between crammed fragments of figures and unrecognizable colour patches. Below the outstretched arms there are appendages resembling wings but of unclear significance. Red-brown with, partly preserved, yellowish-white contour.

PLATE XXXVIA. Malán. (Photograph by Schulz.)

Two lying figures, the larger ca. 45 cm. long. Above very faded elongated standing figure with outstretched arms (see Plate XXXVA.). Next to it, more distinct, a standing figure with a peculiar head. Bothe legs and the two parts sticking out upwards from the hips have light contours. A small space showing, on both sides, bundles of transversal lines is more faded, probably an older picture without any connexion with the superimposed figure. More or less faded red-brown.

PLATE XXXVIB.

A rock painting from the Matopo Hills, Southern Rhodesia, South Africa, representing a lying figure, ca. 50 cm. long, painted over a faded standing figure. The figure is conspicuous amongst surrounding, less prominent figures. Red-brown.

NIRRANDA STREWNFIELD AUSTRALITES, SOUTH-EAST OF WARRNAMBOOL, WESTERN VICTORIA

By George Baker, M.Sc.

List of Contents

Foreword

The Nirranda Strewnfield australites have been discovered at a time when much additional knowledge of the location, concentration density, fragmentation, etching propensities, specific gravity, shape and size variation, sculpture patterns, &c., of south-western Victorian australites has been accumulated, and can thus be applied to the study of this latest discovery, which embraces a considerable number of different forms of australites from a relatively small concentration centre in the vast Australian tektite strewnfield.

Much of the propounded theory of tektite origin is, of necessity, based largely upon conjecture and supposition. After some 150 years of the study of tektites by renowned scientists in various parts of the world, the tektite question as a whole is still remote from an entirely satisfactory solution. It is with this long background of accumulated fact and theory to hand,

associated with an awareness of the important recent advances that have been made in the realm of the aerodynamics of high-speed flow, that the writer feels justified in indicating the need for a detailed study of the geometry of the remarkably symmetrical australite varieties of tektites, and in suggesting that their typical secondary shapes as derived from primary forms can be explained in terms of gas dynamics. It is possible that such an approach may help to take the tektite problem a step further towards an ultimate solution, and at the same time perhaps add something more to the growing field of knowledge relating to the aerodynamics of high-speed flow produced at far greater than ordinary supersonic speeds.

It is the writer's opinion that too much stress has been laid in the past on the idea that australites must have rotated through the earth's atmosphere about an axis, the position of which was parallel to the direction of propagation through the atmosphere. Although rotation is obviously necessary for the initial development of all except the spheres among the primary forms from which the secondary shapes of australites were produced, the likelihood is considered herein that a spinning motion need not have been maintained during the atmospheric phase of earthward flight, i.e. during a phase when the secondary shapes now possessed by australites were impressed upon the original primary shapes.

Introduction

Three hundred and sixty-six australites, which are Australian tektites of late Recent age, were found in January, 1953, along a narrow strip of the south-west Victorian coastline, extending from Childers Cove south-east of Warrnambool, to the Bay of Islands north-west of Peterborough (text figure 1). These australites are registered in the National Museum Rock Collection, Melbourne, as E707 to E1056 and E1099 to E1114.

The strewnfield in which the australites were located, is hereafter referred to as the Nirranda Strewnfield, the name being derived from the post office nearest to the site on which the greatest numbers of australites were found in the district. Nirranda is situated on lat. 38 deg. 30 min. S., and long. 142 deg. 45 min. E., approximately 3 miles inland from the coastline of south-western Victoria, and 18 miles south-east of the City of Warrnambool (text figure 1).

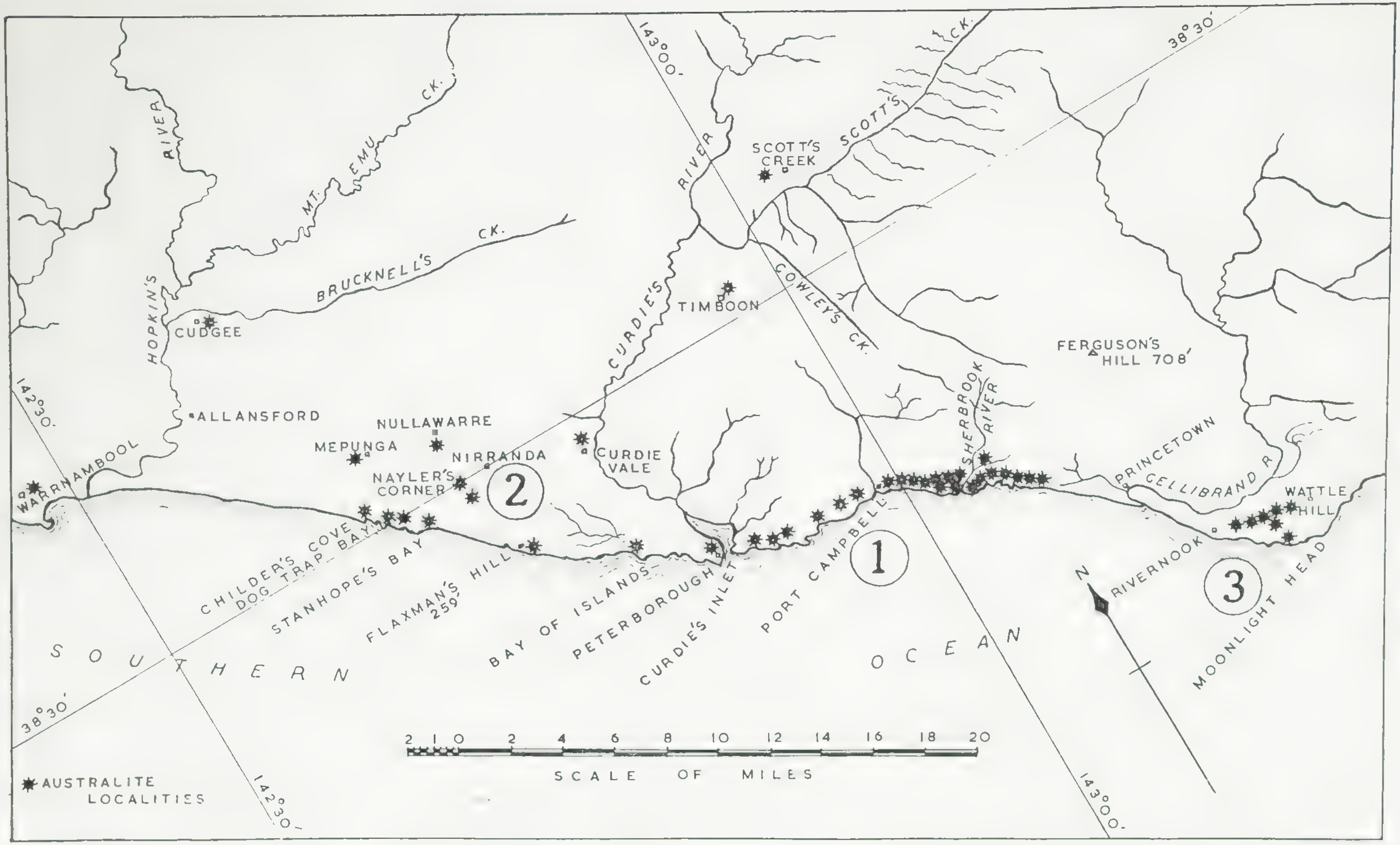


FIGURE 1.

Sketch map of part of the coast of south-western Victoria, extending from Warrnambool in the north-west to Moonlight Head in the south-east.

The asterisks denote different sites from which varying numbers of australites have been obtained.

The three principal strewnfields in this region are indicated by the large figures. No. 1 is the Port Campbell Strewnfield, No. 2 the Nirranda Strewnfield, and No. 3 the Moonlight Head Strewnfield.

Most of the australites from these three strewnfields were located on areas facilitating discovery—areas such as old roads, borrow pits and cliff edges, all relatively free of vegetation, and on areas consisting of naturally bared patches that have been subjected to frequent coastal showers and strong winds, and so are much rain-washed and wind-swept.

In the Nirranda Strewnfield, the majority of the australites were found on such rain-washed and wind-swept patches situated very close to cliff edges. Vegetation, recent soils and the fine to medium size mineral particles have been removed from these patches by wind and by surface run-off of rainwater leaving a veneer of coarser sand in some parts, and a buckshot gravel sprinkled hardened crust in others. Resting upon this hardened crust and coarser sand, which in parts of the strewnfield represents the topmost portion of a former soil horizon, australites have been found in varying numbers, sometimes associated with occasional rounded, partially chipped rocks and numerous flakes of rocks alien to the bedrock of the area. The greater part of the bedrock hereabouts, is Miocene limestone, capped in places with Pleistocene dune limestone. Most of the rock flakes appear to be rejected chips from the process of aboriginal stone implement manufacture. Shell fragments from molluscs used as food by the aborigines, are also a feature of some of the australite-bearing patches. All the geological evidence points to a late Recent age for the australites, substantiating Fenner's (1935, p. 140) belief that australites are " geologically Recent, but historically remote." The precise age is not yet known, but it would not be much more than a few thousand years since the Nirranda Strewnfield australites first arrived upon the surface of the earth. In both the Nirranda and the Port Campbell Strewnfields, the australites occur above an old soil horizon, and in parts of the Port Campbell Strewnfield, a few australites have been unearthed from the top 6 inches of recent soils.

Forty-two per cent. of the australites recently found in the Nirranda Strewnfield are complete or nearly complete forms. Of the remainder, 54 per cent. are composed largely of fragments that can be specifically recognized as coming from the body portions of australites, and among this total are a few nondescript fragments; 4 per cent. of the total are flange fragments. None of the fragments fitted one another, hence each fragment is considered to represent a portion of a different individual australite. The percentage of complete or nearly complete australites that were found with their anterior surfaces facing

upwards, is approximately nine times as great as the percentage found to have the posterior surface upwards. The anterior surfaces pointed earthwards during the atmospheric phase of flight, and since 87·5 per cent. were found on the ground with the anterior surfaces facing away from the earth, it is apparent that the stable position of rest of australites upon the earth's surface is the reverse to their stable position of propagation through the earth's atmosphere.

On the whole, the Nirranda Strewnfield australites are considerably more abraded than the majority from the Port Campbell Strewnfield, and moreover, they are not quite as well preserved as most of the Moonlight Head Strewnfield australites. As a consequence of their worn character, it is possible that some of the australite fragments in the Nirranda Strewnfield may have come from the same original complete form, but having been fragmented a long time ago, they are now largely too abraded and etched to be matched with any degree of certainty. The fact that some of these australites and some of the fragments have a fresher appearance than others is due to their having been buried longer under a protective cover of surface soil, while others have been exposed for longer periods to the abrasive action of wind-borne sand and other erosive agents.

This article deals as comprehensively as has been possible under present circumstances, with the location, distribution, concentration density, physical properties, optical properties, chemical composition, sculpture, shapes, symmetry, statistics and ultra-supersonic flight effects of the recently collected Nirranda Strewnfield australites. Many of these attributes are compared and contrasted with those that have been described for the Port Campbell and Moonlight Head Strewnfields in south-western Victoria, and with those for the Charlotte Waters Strewnfield in Central Australia, and the Nullarbor Plain Strewnfield extending east and west across the southern border between South Australia and Western Australia. The statistics of the Nirranda collection of australites, involving such factors as numbers, dimensions, specific gravities, weights and radii of curvature, are herein presented as frequency polygons and scatter diagrams in order to obviate the use of many cumbersome tables.

Distribution and Concentration

The numbers of australites recovered from various lo alities in the Nirranda Strewnfield are as follows:

Childers Cove	8
Nayler's Corner, Nirranda	3
North-east end of Bay of Islands, Peterborough	3
Half a mile south-east of Flaxman's Hill	11
North-west corner of Dog Trap Bay ..	1
Middle of Dog Trap Bay	2
North-east corner of Dog Trap Bay ..	5
Three-quarters of a mile south-east of Nayler's Corner	1
"Errawallun" homestead, 1 mile south of Nullawarre P.O. (donated by Mrs. A. Mathieson)	1
North-east corner of Stanhope's Bay ..	331
Total	366

Earlier discoveries of a small number of australites from other localities in this region are known from specimens in the National Museum Collection, Melbourne. One is from Cudgee, one from Narrarnhuddut, Scott's Creek, and one from Warrnambool. Three others from the Warrnambool District, formerly in the Warrnambool Museum Collection, are now lodged in the collection of the South Australian Museum, Adelaide. Another one was recorded from Mepunga by Dunn (1912, p. 12). One collected from Curdie's Inlet some years ago has been chemically analysed (Summers, 1913, p. 190). A few others known to have been collected in recent years include two from Timboon and two from Curdie Vale.

For comparison with these numbers in the Nirranda Strewnfield, the numbers are given for neighbouring strewnfields. Thus twenty australites have been discovered west and south-west of Wattle Hill in the Moonlight Head Strewnfield (15 described by Baker, 1950, p. 35), and 1,487 australites are known from the stretch of coast extending from 1 mile south-east of Curdie's Inlet, through Port Campbell township to 3 miles south-east of the Sherbrook River in the Port Campbell Strewnfield (Baker, 1937, 1940*a*, 1944, 1946, and Baker and Forster, 1943).

Since the initial discovery of 331 australites at Stanhope's Bay, a further 223 specimens, comprising complete forms and fragments of australites, have been collected from this site, and donated to the National Museum of Victoria over the past year and a half, by Colin Drake of Warrnambool and Brian Mansbridge of Allansford, Victoria.

The Nirranda Strewnfield has its greatest concentration of australites near Stanhope's Bay, where 91 per cent. of the total for the field were discovered. Three hundred and thirty-one australites, including complete forms, nearly complete forms and separate fragments were found on a small area approximately 350 yards by 200 yards in size. This represents the most densely populated australite centre so far known in south-western Victoria and, for that matter, is probably also the most densely concentrated centre in the whole of Australia. Three hundred and ten of the 331 australites from this site near Stanhope's Bay were the outcome of four hours searching by E. D. Gill (59), A. E. Gill (108), M. Gill (8), M. K. Baker (55) and G. Baker (80) in January, 1953. The remaining 21 from this small area were subsequently collected by R. T. M. Pescott (9) and E. D. Gill (12).

Comparison with Concentrations in Other Australian Strewnfields.

Some idea of the comparative population density of australites in various parts of Australia can be obtained by combining the Moonlight Head–Port Campbell–Nirranda Strewnfields, and comparing the result with that of two other areas—Charlotte Waters and the Nullarbor Plain—from which large collections have been made over extensive tracts of territory. The areas of distribution, numbers found and concentration densities for these three major strewnfields, are compared in Table I.

TABLE I.

—	Moonlight Head–Port Campbell–Nirranda Strewnfields.	Charlotte Waters Strewnfield.	Nullarbor Plain Strewnfield.
Area embracing discovery sites	150 square miles ..	8,000 to 9,000 square miles	30,000 square miles
Numbers found	1,877	7,184	3,920
Concentration density	12·5 per square mile	0·8 per square mile	0·13 per square mile

Outlying areas at Scott's Creek, Timboon, Cudgee and Warrnambool have been excluded from the calculations for the Moonlight Head–Port Campbell–Nirranda Strewnfields, and the

area considered is thus a strip of coast 50 miles long by 3 miles wide. The specimens comprise the Baker Collection of 1,352 Port Campbell australites and 20 Moonlight Head australites, 83 from Port Campbell in the Melbourne University Geological Collection, 366 Nirranda Strewnfield australites in the National Museum Collection, Melbourne, and a few in private collections.

The Charlotte Waters Strewnfield australites comprise the Kennett Collection described by Fenner (1940, p. 305) and the Nullarbor Plain Strewnfield australites comprise the Shaw Collection also described by Fenner (1934, p. 62).

The comparative values shown in Table I for these three major strewnfields indicate that the greater concentration of australites per square mile is in south-western Victoria. Smaller centres within this region are even more densely populated than is indicated by the overall figures in column 1, Table I, for example, the occurrence of 331 australites over an area 350 yards by 200 yards in extent at the Stanhope's Bay tektite site. This observation relating to the density concentration of australites has even greater significance when it is considered that opportunities for successful searching in the relatively well-vegetated region of south-western Victoria are not as great as in the sparsely vegetated gibber regions and dry plains of the other two strewnfields included in this comparison.

In the three south-western Victorian strewnfields, the present stream patterns (cf. text figure 1) bear little or no relationship to australite distribution, and there is no evidence to indicate spreading or concentration by former streams. In the main, it is considered that the majority of the australites were recovered from more or less the positions where they originally fell as extra-terrestrial bodies. However, it cannot be assessed how much the Australian aborigines, nor how much native birds such as emus and bush turkeys have been concerned in australite distribution in these parts. Australites were utilized for various purposes by the aborigines, and have been found in the gizzards of emus and bush turkeys. There is evidence of the continued use of australites by living tribes of Australian aborigines. A verbal communication from Mr. H. R. Balfour of Toorak, Victoria, discloses that the aborigines of the Woomera region in Central Australia call australites "emu-stones," by virtue of the purpose for which they are employed. Mr. Balfour states that the australites are wrapped up in balls of feathers by the aborigines, and these are then thrown towards flocks of emus. Being especially endowed with a natural inquisitiveness,

the emus approach these objects for closer inspection. While absorbed in their investigation, they are speared by the aborigines. Their gizzards often contain a number of stones, usually black in colour, a large proportion of which are frequently australites. This practice has been a feature of aboriginal food-hunting for many years past, and it therefore seems possible that occasional small concentrations of worn and broken australites could well have been brought about by some such, or allied aboriginal custom, particularly when it is recalled that aboriginal chipped flints and shell-food remnants are common associates of the australite-sprinkled areas along the coastline of south-western Victoria. The worn character of these australites is also partly due to minor amounts of sand-blasting where exposed on the wind-swept patches, while some of the wear on some of the australites may have been due to " carry polish " during utilization by the aborigines.

On a barren patch of ground near Childers Cove, from which eight australites were recovered, are numerous shell fragments and chipped flints testifying to previous occupation by the aborigines. At Nayler's Corner, 2 miles inland from the coast, where three australites were found, there was no evidence to indicate aboriginal occupation. This site is a small triangular patch of ground at a road junction, and the area has evidently been bared by road-making activities and stripped of the top few inches of soil, thus exposing the australites. At several of the other sites where australites were discovered, namely near Flaxman's Hill, Dog Trap Bay and the Bay of Islands near Peterborough, there is further evidence in the form of occasional chipped flints and shell fragments that these coastal areas were within the region of aboriginal middens and camping grounds.

Forms of Australites Represented

The collection of australites from the Nirranda Strewnfield contains a generally representative variety of the usual australite shapes recovered from other strewnfields in Australia, but shows minor variations in some respects from the Port Campbell and Moonlight Head Strewnfields further to the south-east. The collection contains a greater percentage of fragments of hollow forms of australites (cf. Plate II) than so far encountered in either the Port Campbell or the Moonlight Head Strewnfields, and also a greater percentage of lens-shaped forms (cf. Plate I

figures 3 and 7). Like the Moonlight Head Strewnfield australites, those from the Nirranda Strewnfield show a complete absence of small forms such as flat circular discs, bowl-shaped forms and oval plate-like forms (forms that were especially searched for); this is in contrast to the Port Campbell Strewnfield from which a number of these particular shapes have been recovered (cf. Baker, 1937, 1940*a*, 1946). Aberrant forms (cf. Baker, 1946) are also wanting in the Nirranda, as in the Moonlight Head Strewnfield.

External features shown by the australites from the Nirranda Strewnfield are typical in consisting of bubble-pitted posterior (back) surfaces (see Plates I to IV) and of flow-ridged, flow-lined anterior (front) surfaces carrying few bubble pits and etch marks (see Plates I, II and IV). Some of the forms are flanged (see Plates I and II).

The percentage occurrence and the numbers of the various australite shape groups represented in the Nirranda Strewnfield, are compared in Table II with those from the Port Campbell and Moonlight Head Strewnfields.

Owing to low numbers in the various shape groups of the Moonlight Head Strewnfield australites, and the fact that less than half the number of shape groups is represented, despite careful searching of the area for more examples, the percentage values for several of the shape groups may be too high. Populations are sufficiently large for statistical significance in all of the Port Campbell and most of the Nirranda Strewnfield australite shape groups.

The percentage distributions of shape groups and fragments among the australite populations of the Charlotte Waters and the Nullarbor Plain Strewnfields respectively have been calculated from the numbers in each shape group and the number of fragments listed by Fenner (1934, 1940) for the Shaw and Kennett collections. The results are compared in Table III with the percentage distributions obtained by combining the total numbers in each shape group and fragment group for the three strewnfields in south-western Victoria. Slight re-arrangements have been made to Fenner's lists for the Shaw and Kennett collections in order to conform with the grouping of forms and fragments from the combined Nirranda–Port Campbell–Moonlight Head Strewnfields.

TABLE II.

Shape Group.	Nirranda Strewnfield.		Port Campbell Strewnfield.		Moonlight Head Strewnfield.	
	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.
Buttons	32	8·7	245	17·0	6	30·0
Hollow button	1	0·3	..	..	..	..
Lenes	55	15·0	57	3·9	2	10·0
Ovals	37	10·1	100	7·0	3	15·0
Boats	9	2·5	40	2·7	..	..
Canoes	2	0·5	12	0·8	..	..
Dumb-bells	3	0·8	16	1·1	..	..
Teardrops	2	0·5	21	1·5	..	..
Round cores ("bungs") ..	4	1·1	20	1·4	..	..
Elongate cores	10	2·8	12	0·8	1	5·0
Round discs	..	..	14	1·0	..	..
Oval plates	..	..	10	0·7	..	..
Bowls	..	..	9	0·6	..	..
Aberrants	..	..	10	0·7	..	..
Round form fragments* ..	127	34·7	234	16·2	2	10·0
Elongate form fragments ..	19	5·2	114	7·9	2	10·0
Hollow form fragments ..	10	2·8	23	1·6	..	..
Complete flanges (detached)	2	0·5	18	1·2	..	..
Flange fragments ..	14	3·8	313	21·7	1	5·0
Nondescript fragments ..	39	10·7	177	12·2	3	15·0
Totals	366†	100·0	1,445‡	100·0	20	100·0

KEY TO TABLE II.

* The term "round forms" throughout this article refers to australites that are circular in plan aspect (cf. text figure 13 and Plates I and II).

† Four other examples known, but not classified (also 223 examples recently discovered at Stanhope's Bay).

‡ Forty-two other examples known but not classified.

Table III serves to stress certain trends that are common among australites generally. These trends are—(i) the rarity of such forms as the hollow buttons, the canoes, dumb-bells, cores, round discs, oval plates, bowls and aberrants among the complete forms, (ii) the rarity of flanges detached as complete entities (cf. Plate I, figures 4 and 5) from their parent forms, (iii) the preponderance of round forms such as buttons and particularly lenses, over elongated forms (Note: Dunn (1912, p. 3) found that 66 per cent. of the australites from Mt. William in the Grampians, Victoria, were "button-shaped or forms produced from them"), and (iv) significant variations from strewnfield to strewnfield in the percentage populations of some of the

various shape groups. Such a variation is most marked amongst the group of lens-shaped australites. Variation in the groups of elongated australites, however, is of no marked significance. The significant variations from locality to locality in the lens

TABLE III.

Shape Group.	Combined South-West Victorian Strewnfields.		Nullarbor Plain Strewnfield.		Charlotte Waters Strewnfield.	
	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.
Buttons	283	15·5	275	7·0	686	9·6
Hollow button	1	< 0·01	..	..	..	..
Lenses	114	6·2	1,038	26·6	3,243	45·2
Ovals	140	7·7	168	4·3	740	10·3
Boats	49	2·7	171	4·4	323	4·5
Canoes	14	0·8	81	2·0	10	0·1
Dumb-bells	19	1·0	70	1·8	67	0·9
Teardrops	23	1·3	134	3·4	62	0·8
Round cores (" bungs ") ..	24	1·3	..	..	6	0·08
Elongate cores	23	1·3	..	..	..	..
Round discs	14	0·8	56	1·4	..	..
Oval plates	10	0·5	..	..	10	0·1
Bowls (or " helmets ") ..	9	0·5	..	..	2	0·02
Aberrants	10	0·5	..	..	91	1·3
Round form fragments ..	363	19·8	954	24·3	273	3·8
Elongate form fragments ..	135	7·4	603	15·4	484	6·7
Hollow form fragments ..	33	1·8	28	0·7	11	0·2
Complete flanges (detached)	20	1·1	..	..	..	..
Flange fragments ..	328	17·9	..	..	1	..
Nondescript fragments ..	219	11·9	340	8·7	1,175	16·4
Totals	1,831*	100·0	3,920	100·0	7,184	100·0

* Forty-six other examples known, but not classified, and hence not included in the total (also 223 subsequently discovered at Stanhope's Bay).

group, is largely a reflection of the state of preservation of australites. A greater number of round forms become classified with the lens group, the more the button-shaped australites are eroded and lose all traces of their flanges. Being better preserved, there is thus a greater percentage of buttons than lenses in the combined South-western Victorian Strewnfields (Table III). Being much more abraded, the position is reversed in both the Nullarbor Plain and the Charlotte Waters Strewnfields.

Percentage variations among the groups of fragments of the australites are partly a reflection of variations of the percentage populations of complete forms from which they were derived, but also may be influenced by two other factors, namely (i) as yet incomplete field sampling in some of the strewnfields, and (ii) variations in the processes of erosion from strewnfield to strewnfield. The search for australites in the Nirranda Strewnfield, as in the Port Campbell and Moonlight Head Strewnfields, has been as thorough as possible in the time available. All fragments of all visible sizes and shapes, as well as all complete and nearly complete forms exposed to view were collected, hence the collection is as representative as possible. Herein may lie the explanation of the abundance of flange fragments in the three combined strewnfields in south-western Victoria, compared with their absence from the Nullarbor Plain Strewnfield and the record of one only among 7,184 specimens collected from the Charlotte Waters Strewnfield. Since in each collection there are numerous specimens that must have possessed flanges originally, it is doubtful if all flange fragments in one large strewnfield (Nullarbor Plain), and all but one in another large strewnfield (Charlotte Waters), were destroyed by erosion, while so many (nearly 18 per cent. of the total number of australites found) remained in a third large strewnfield (South-western Victoria). It would be even more doubtful that the flanges were all lost before the australites landed on the surface of the earth, in the strewnfields from which they are not recorded. It is therefore likely that flange fragments have either been overlooked or discarded in collecting from the Nullarbor Plain and Charlotte Waters Strewnfields.

Complete Forms

The lens-shaped group (Plate I, figures 3 and 7) is the most abundantly populated shape group among the Nirranda Strewnfield australites, followed by oval-shaped and button-shaped forms (see Table II). Together, these three shape groups contain 80 per cent. of the complete and nearly complete australites discovered in this strewnfield. Except where much abraded, the various individuals of each shape group reveal similarities to most other properties possessed by australites described from a number of localities in Australia. Variations in weight, size and specific gravity are shown in Table IV and in text figures 2 to 11.

Only three of the button-shaped forms (cf. Plate I, figures 1 and 2) and one oval-shaped form are complete in possessing the entire flange and entire body portion preserved. The entire flange is still attached to the body portions of the button-shaped forms (E766, E818, E1016), but the complete oval-shaped form (reg. no. E836) was found *in situ* as three pieces—complete flange (detached) and two halves of the body portion—which all unite to constitute a complete oval with flange. The pieces were partially, but loosely embedded in soil, with the anterior surface exposed to view.

Several of the button-shaped forms still retain over one quarter and under two-thirds of the flange still attached to the body portion (cf. Plate I, figure 6), and a number possess attached minute flange remnants (Plate I, figure 8) that serve to indicate the original shape group of the australite. A few forms that might normally have been classified with the lens-shaped group of australites, reveal, on closer inspection with a low power hand lens, vestiges of smooth areas at the edges of the posterior surfaces; these are referred to as "flange bands." The flange bands represent the original surfaces of union between flange and body, and hence round forms possessing them were australite buttons and not lenses. These bands are usually 1 to 2 mm. wide, being a millimetre or so narrower than the average width of the flanges themselves (cf. text figure 6) as measured across their posterior surfaces. Freshly broken away flanges leave an annular band around the equatorial edge of the posterior surface of originally flanged australites. When not excessively bubble-pitted, this band shows a higher vitreous lustre than other parts of the posterior surface. On weathering, however, it becomes dulled and etched, and may in time become almost obliterated and practically indistinguishable as a discriminating feature. Under these conditions, the remaining body portion becomes, to all intents and purposes, a member of the lens-shaped group of australites. Where such degrees of wear have been attained, it thus becomes virtually impossible to distinguish lenses derived by loss of material during flight through the atmosphere, from the lenses derived from buttons by loss of all vestiges of flanges due to agents of weathering acting upon them after landing upon the earth's surface.

Many of the Nirranda Strewnfield australites that are grouped as oval-shaped, have outlines in plan aspect that are not far removed from the button- and lens-shaped forms which

are circular in plan. Variations of as little as 1 mm. and up to 2 mm. between the two diameters of such forms, seem to be sufficient to warrant their classification with the oval group, especially where the forms are as small as 10 mm. (or less) across, when a difference of 1 mm. between the two diameters constitutes 10 per cent. (sometimes up to 16 per cent.) of the total measurements. In such forms, differences in the two diameters are not due to subsequent erosion, since many of them still retain flange remnants, indicating that the edges of the body portions, across which the measurements were made, have not been differentially worn. Few of the ovals possess well-developed flanges, many show well-marked rims; one example only has a complete flange (E836), and one shows evidence of the rim being extended outwards in the initial stages of flange formation (see Plate IV, figure 24).

Among the more elongated forms of the Nirranda australites, one of the canoe-shaped forms (Plate IV, figures 17-19) is larger than the upper limits (30 mm.) set out by Fenner (1940, p. 313) for this group. The specimen is 31·5 mm. long, and is the largest known canoe-shaped australite so far recorded from the Australian tektite strewnfield.

The teardrop-shaped forms (cf. Plate IV, figure 22) are rather worn, and have lost the greater part of the "tail" portions. The dumb-bell (Plate IV, figure 20), teardrop and boat-shaped (Plate IV, figure 21) groups contain forms that are of medium to small size compared with some examples from other Australian strewnfields.

Cores (Plate III), which constitute some 9 per cent of the Nirranda Strewnfield australites, are in the proportion of 2 elongate cores to 1 round core. Round and elongate cores have been described elsewhere (Baker, 1940*b*, p. 492), and some of the examples from the Nirranda Strewnfield show comparable and characteristic flaked equatorial zones, partly modified by secondary flaking processes resulting from agencies acting upon them while they lay upon the earth's surface. In their initial formation, however, it is believed that these flaked equatorial zones were developed by fusion stripping and perhaps some ablation during atmospheric flight.

Fragments of Various Forms.

Among the groups of the fragments of australites, those from round forms consist of pieces broken from (i) equatorial regions of buttons, and thus show flange remnants or traces of

the flange band, sometimes a little of both, (ii) the central core or body portions of buttons and lenses, (iii) posterior surfaces of buttons and lenses, and (iv) anterior surfaces of buttons and lenses.

Elongate-form fracture fragments consist of pieces showing indisputable evidence of derivation from oval-, boat- and dumb-bell-shaped australites. No fragments were found of either teardrop- or canoe-shaped forms. Occasional smaller fragments grouped with the round-form fragments might have come from the body portions of certain elongate forms of larger size, but since there is nothing to indicate this, such fragments are classed with the round-form fragments on the grounds that round forms comprise the greatest populations among australites, and hence should provide greater numbers of fragments on fracturing.

The largest core fragment in the Nirranda collection of australites, is reg. no. E795, which weighs 23·92 grams, and would, on reconstruction, represent a large elongate core measuring 66 x 35 x 19 mm. Such a form would weigh approximately 96 grams, and would thus have been heavier, and larger, than the biggest complete form (reg. no. E922 (Plate III, figure 16) weighing 55 grams) in the collection.

Most of the flange fragments provide evidence of having been originally attached to button-shaped australites. Two are complete or nearly complete flanges (Plate I, figures 4 and 5) detached entire from their parent button-shaped forms; their diameters, &c., are set out in Table IV. Only one flange fragment, constituting one half of the original, provides adequate proof of derivation from an oval-shaped australite. Its dimensions are—25·5 mm. long and 20 mm. across, while its width measured over the posterior surface is 2·5 mm. The detachment of large portions of flanges and of complete flanges from their respective parent forms, is brought about partly by etching, and partly by weakening of the contacts with body portions by various means. The detached flanges become reduced in size by impact with other objects on the ground during surface run-off drainage; at the same time, small fragments are fractured from certain parts of flanged australites, while more firmly attached portions of the flanges remain on the parent form (cf. Plate I, figure 6).

The hollow forms of australites in the Nirranda Strewnfield were all broken on discovery, some to much greater extents than others. Some have been shattered to form large, concavo-convex fragments resembling broken fossilized egg-shells of

Aepyornis. Others are only broken on one surface (Plate II, figure 11), or merely punctured like the example figured in Plate II, figures 9 and 10, but still revealing the original form of the hollow australite. Ten fragments of hollow forms were discovered, and two nearly complete hollow forms. One (Plate II, figures 9 and 10), with a small hole leading inwards from the anterior surface contained abundant fine sand and clay constituents that had filtered into the internal cavity. The cubical contents of the internal bubble contained by this hollow form have been determined as 1·18 cc. by introducing a good wetting fluid (toluene) through the small hole by means of a fine capillary tube, and weighing the australite with and without the fluid, on an air-damped balance. It cannot be decisively determined whether the fracture fragments from the hollow australites were broken by impact on landing, or by subsequent natural effects (or by accident) while resting upon the earth's surface. Judged from the degree of erosion shown by the fragments, breakage evidently occurred a long time ago; the same applies to the more complete hollow button figured on Plate II, figure 11. The almost complete hollow button (Plate II, figures 9 and 10) was apparently punctured by processes involving etching to a great extent, for the reason that the outer end of the opening leading into the internal cavity occurs 2·5 mm. below the external front polar regions of the anterior surface, and is situated at the junction of several radiating grooves (cf. Plate II, figure 9). Two of the hollow form fragments are large enough to furnish the dimensions of the original internal bubbles. One of these was 14·7 mm. across, and the other, 16·6 mm. The cubical contents of these bubbles would have been 1·64 cc. and 1·88 cc. respectively.

The thickness of the bubble walls of the hollow form fragments varies from 0·5 mm. to 7·0 mm. Fragments broken from the equatorial regions (E714), where the anterior surface meets the posterior surface, usually show a marked thickening of the bubble walls in the region where flanges usually form on solid australites. Flanges are usually the exception rather than the rule on hollow australites from other parts of Australia, so that it is of interest to find remnants of well-developed flanges attached to two hollow forms (Plate II, figures 9, 10 and 11) among the Nirranda Strewnfield australites. Fragments from forms belonging to shape groups other than the hollow, button-like examples described, also contain bubbles of more than usual size. These range in size from 4 mm. as in reg. no. E796, and

upwards in diameter. One of the hollow form fragments (E830) shows evidence of inward collapse of part of the bubble walls. The collapse occurred in the walls of the internal bubble nearest the anterior surface of the australite, at a time when secondary fusion and ablation had resulted in reduction in thickness of the anterior walls, and so partial collapse of the bubble occurred during atmospheric flight. The plastic glass in the region of collapse became inrolled on to the inner walls of the internal bubble, but solidified before much flowage occurred.

Size, Weight and Specific Gravity of the Members of the Various Shape Groups.

Where sufficiently well-preserved to provide the necessary information, each australite in the collection has been measured to ascertain (i) the depth and diameter of forms that are circular in plan aspect, (ii) the length, width and depth values of elongated forms, and (iii) the width values of flanges, including those still attached to body portions, and detached flange fragments. All the specimens, whether complete, nearly complete or fragmentary, have, after cleaning, been separately weighed in air on an air-damped chemical balance. The specific gravity value of each has been determined in toluene at 20°C., the results listed in Table IV being recalculated values for air-free, distilled water.

The size measurements, the weight values and the specific gravity values are given in Table IV for the different shape groups only. Individual values for the different australites found in the Nirranda Strewnfield have been plotted in the frequency polygons and scatter diagrams shown in text figures 2 to 11.

Size

All values obtained from the measurement of depth, diameter, length and width of the Nirranda Strewnfield australites are recorded to the nearest 0·5 mm. in Table IV. Each depth value represents the maximum thickness measured between the front and back poles of the curved anterior and posterior surfaces respectively (cf. text figure 19). Table IV. reveals that the largest complete forms are in the core group, the smallest in the lens-shaped group.

The relationships betwen the depths and diameters of the round australites (i.e. buttons, lenses and round cores) are indicated in figure 2.

Table IV.

Weight, Specific Gravity and Size Values of Nirranda Strewnfield Australites.

	Shape Group.	General Classification.	Number Measured.	Range of Weight in Grams.	Average Weight in Grams.	Range of Specific Gravity.	Average Specific Gravity.	Range of Depth in mm.	Average Depth in mm.	Range of Diameter in mm.	Average Diameter in mm.	Range of Length in mm.	Average Length in mm.	Range of Width in mm.	Average Width in mm.	Range of Flange Width in mm.	Average Flange Width in mm.
COMPLETE FORMS	Buttons	A1	32	1·424–4·390	2·662	2·3[illegible]–2·45	2·407	6–15	8·5	9–23·5	13	..	..	..	..	2–3	2·5
	Hollow Button ..	..	1	..	19·283	..	2·[illegible]	.	1[illegible]·5	.	33	.					[illegible]
	Lenses	A2	55	0·247–3·409	1·395	2·37–2·47	2·409	2–13·5	6·5	7–22·5	12·5	..	..	..	..	..	
	Ovals	A3	37	[illegible]	1·[illegible]44	2·39–2·46	2·413	3–12	6	..	..	7·5–22·5	13	6–21	11		[illegible]
	Boats	A4	9	[illegible]	1·742	[illegible]	2·399	4·5–7	6	..	..	14–30	18·5	9–12·5	11		[illegible]
	Canoes	A5	2	1·502–3·254	2·378	2·39–2·41	2·397	6·5–8	7	..	..	23–31·5	27	10–13	11·5		
	Dumb-bells ..	A6	3	0·839–1·718	1·223	2·41–2·42	2·415	3–5	4	..	..	21–26·5	24·5	5–8·5	7	..	
	Teardrops ..	A7	2	1·123–2·013	1·568	2·40–2·43	2·415	1–1·5 (tail) 7–8 (body)	7·5	..	..	17–21	19	3–4 (tail) 10 (body)	3·[illegible] 10 (body)		
	Cores—round ..	..	4	3·894–10·176	6·736	2·39–2·43	2·406	10–15	13	16–24	20						
	Cores—elongate ..	..	10	1·309–55·100	11·157	2·40–2·46	2·419	6–15·5	13	..	..	14–39	22·5	10·5–[illegible]4	[illegible]7·5		
FRAGMENTS	Fragments of round forms (a) ..	B1	127	0·274–4·226	1·210	2·36–2·47	2·408	(e) 5·5–14	10	(f) 13·5–25	(f) 18	..	..	..	..	1·5–[illegible]	[illegible]
	Fragments of elongate forms	B2	19	0·977–23·920	3·282	2·39–2·44	2·406	(c) 6·5–19	(c) 9	..	..	(b) 22–60	(b) 35	(d) 10–35	(d) 14		[illegible]
	Fragments of hollow forms	..	10	0·656–7·792	2·954	2·38–2·41	2·393	..	..	[illegible]	[illegible]·5						
	Detached complete flanges	B1	2	0·538–1·073	0·806	..	2·391	..	..	17–23	20	.	.	..			
	Flange fragments ..	B1	14	0·130–0·553	0·264	2·38–2·43	2·407	..	..	..	..	..	..	..	..	2[illegible]	[illegible]
	[illegible] fragments	B3	[illegible]	[illegible]	[illegible]	[illegible]–2·47	2·4[illegible]	.									
	Total		366	0·[illegible]	1·826	2·36–2·47	2·4[illegible]	2–1[illegible]		[illegible]		[illegible]		[illegible]			

Total Weight 668·396 gms.

(a) Pi[illegible] from body and p[illegible] of body + flang[illegible] (b) 70 specimens; (c) 17 specimens; (d) 16 specimens; (e) 36 specimens; [illegible] higher value [illegible]tained by re[illegible]

The distribution (text figure 2) is confined to a relatively narrow zone above the line of unit gradient, showing that diameter is always greater than depth in any given round form. There is revealed a transitional increase in both depth and

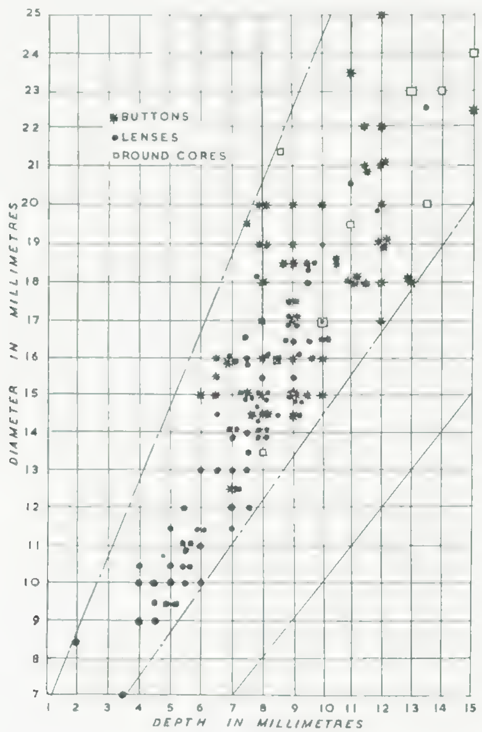


FIGURE 2.

Scatter diagram showing depth-diameter relationships for round forms of the Nirranda Strewnfield australites.

diameter from lenses, through buttons and smaller cores, to the larger cores, with depth increasing as diameter increases. A noteworthy feature of the distribution is that a number of forms with the same diameter have different depth values, and a number with the same depth have different diameter values. This relationship holds for different values of both depth and diameter. There are, for example, 17 buttons and lenses having the same diameter of 15 mm., but depth variability of from 6 to 10 mm., indicating that similar original forms have been ablated to different degrees to produce secondary shapes of the same ultimate diameter and different depths. There are also 24 buttons and lenses with the same depth value of 9 mm., but with diameters varying from 14·5 mm. to 20 mm., thus indicating that

original forms of slightly different size have been ablated to different degrees in order to produce secondary shapes of the same ultimate depth. The indications of the production of end members agreeing with one another in certain measurements, from primary forms of originally different size, receive further support from a study of the relationships of the depths and diameters to the radii of curvature of the back and front surfaces respectively (see text figures 23–26).

The frequency polygons for the depth and diameter values of these round forms of australites are shown in text figure 3.

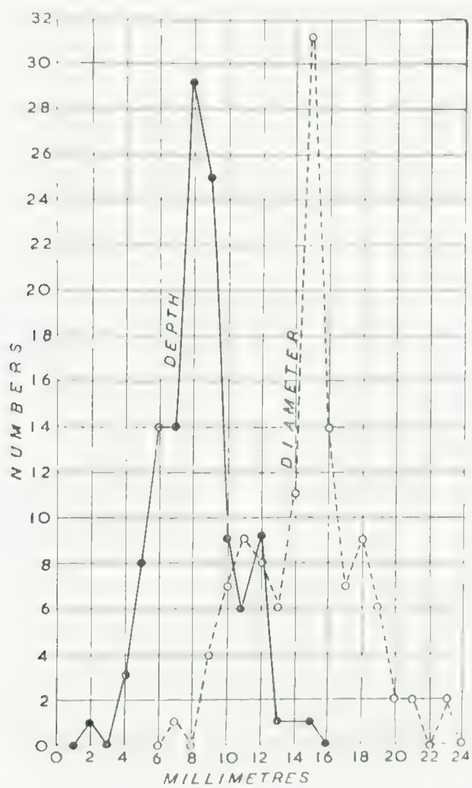


FIGURE 3.

Frequency polygons for depth and diameter values of round forms of the Nirranda Strewnfield australites.

The depth and diameter values (text figure 3) have been plotted to the nearest 1·0 mm. The respective modes, 8 for the depth values, and 15 for the diameter values, bear out the observations that in most of these round forms of australites each diameter value is usually approximately twice the depth value.

Consequently the appearance of these australites in side aspect (or in silhouette) is frequently lenticular (cf. text figure 19). A common size among these button- and lens-shaped australites is that provided by the modes in text figure 3, namely 8 mm. by 15 mm.

The population of complete individuals in each of the remaining six australite shape groups is insufficient for their size relationships to be shown satisfactorily by means of either scatter diagrams or frequency polygons, although the group of the oval-shaped australites yields relatively satisfactory scatter diagrams for length–depth and length–width relationships (see text figures 4 and 5).

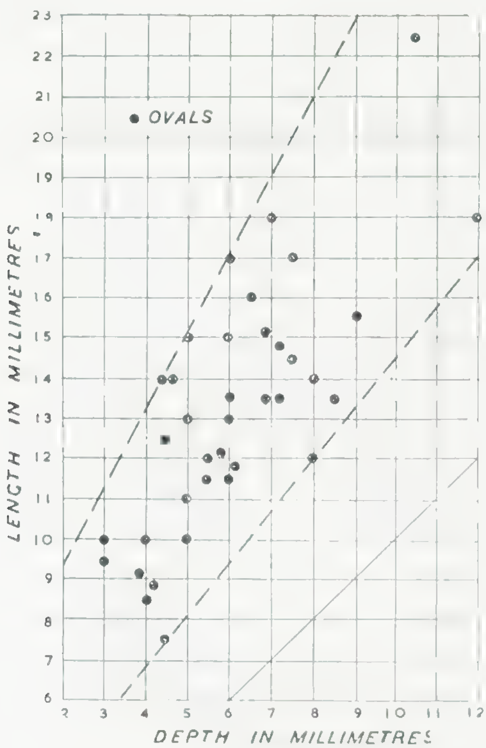


FIGURE 4.

Scatter diagram for length–depth relationships of the oval-shaped Nirranda Strewnfield australites.

In text figures 4 and 5, each distribution falls into a narrow zone above the line of unit gradient, and both depth and width increase generally as length increases. A few specimens with the same depth (e.g. 6 mm.) have length variation (from 11·5

mm. to 17 mm.), and a few with the same length (e.g. 14 mm.) vary in depth (from 4·5 mm. to 8 mm.), while comparable trends are also shown for length–width relationships, although the variations are not quite as pronounced. Such relationships are somewhat analogous to those already outlined in the groups of button- and lens-shaped australites.

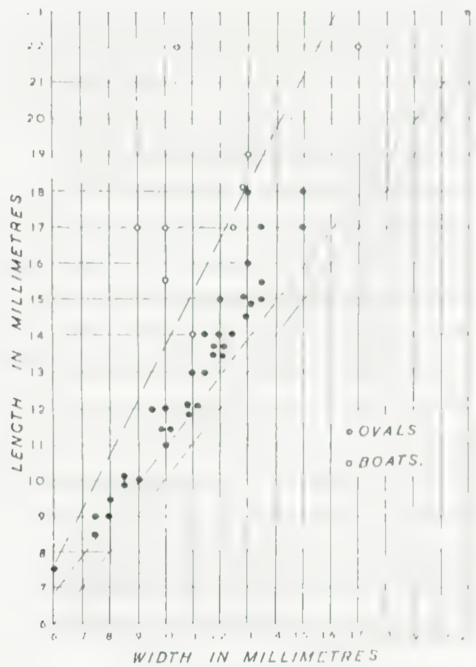


FIGURE 5.

Scatter diagram for length width relationships of the oval-shaped Nirranda Strewnfield australites.

In text figure 5, the relationship between length and width for the small population of boat-shaped australites is such as to reveal a similar increase of width with increased length as in the oval-shaped group, but there is a much wider scatter.

The relationship of widths to numbers of flanges encountered in the strewnfield, is shown in text figure 6. Seventy-two width measurements were made on (i) flanges still attached to both complete and partially fragmented button-shaped australites, (ii) two flanges detached as complete entities from buttons and one from an oval, and (iii) several flange fragments comprising from one sixth to just over one half of the original, mainly from buttons, with one from an oval.

The mode of the frequency polygon (text figure 6) occurs at the 3 mm. width value, and this corresponds with the calculated average value for flange width. The measured range in the width of flanges is 1·5 mm. to 5 mm. (see Table IV), but the range in the frequency polygon (text figure 6) is recorded as 2 to 5 mm., because the measured values have been plotted to the

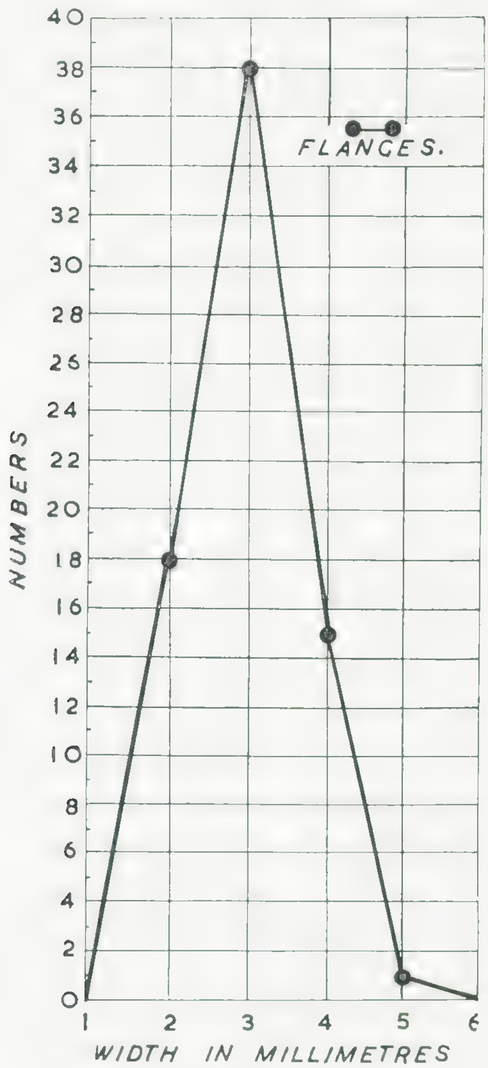


FIGURE 6.

Frequency polygon for widths of flanges.

nearest 1·0 mm. The widths of the flanges were obtained by measuring across their posterior surfaces, from the outer (i.e. equatorial) edge to the inner edge (or chin–cf. text figure 15).

Weight.

The smallest weight value of a complete form among the Nirranda Strewnfield australites is 0·247 grams, for a small lens (reg. no. E781) measuring 7 mm. in diameter and 3·5 mm. in depth, and having a specific gravity of 2·434. There are 21 fragments with lower weight values than this, the lightest fragment weighing only 0·090 grams.

The largest weight value obtained is 55·100 grams, for a large elongate core (reg. no. E922) measuring 39 mm. long, 34 mm. wide and 28 mm. deep, with a specific gravity of 2·437. This specimen (Plate III, figure 16), from "Errawallun" homestead, one mile south of Nullawarre P.O., was found under a tree in 1910, by Mr. A. Mathieson, Snr., while sheltering from a storm.

The total weights, ranges in weights and average weights for complete australites, and for all specimens including fragments, from the Nirranda Strewnfield, are compared in Table V with those for the Port Campbell and the Moonlight Head Strewnfields.

TABLE V.

Strewnfield.	Number of Specimens Found.	Number of Specimens Weighed.	Total Weight in Grams.	Average Weight in Grams.	Weight Range in in Grams.	Average Weight of Complete Forms in Grams.	Weight Range of Complete Forms in Grams.
Nirranda ..	370	366	668·396	1·826	0·090 to 55·100	2·560 (155 spp.)	0·247 to 55·100
Port Campbell ..	1,487	573	830·322	1·549	0·054 to 56·482	2·734 (212 spp.)	0·065 to 56·482
Moonlight Head ..	20	15	51·052	3·403	0·134 to 25·869	4·912	0·837 to 25·869

Because of low numbers of specimens, weight values for the australites from the Moonlight Head Strewnfield have little statistical significance in comparisons with those of the Nirranda and Port Campbell australites; nevertheless, the numbers listed for the Moonlight Head Strewnfield represent the total population known, and searches in recent years have yielded no more specimens.

Numbers are satisfactory for significance in the Nirranda and Port Campbell Strewnfields, and the fact that the average for all specimens weighed, including both complete specimens and fragments, is lower for Port Campbell than for Nirranda australites, can be explained as a function of the discovery of a greater number of smaller fragments in the Port Campbell Strewnfield, where the average weight of complete forms is a little higher.

The weight distribution of complete forms of australites from the Nirranda Strewnfield is shown in text figure 7.

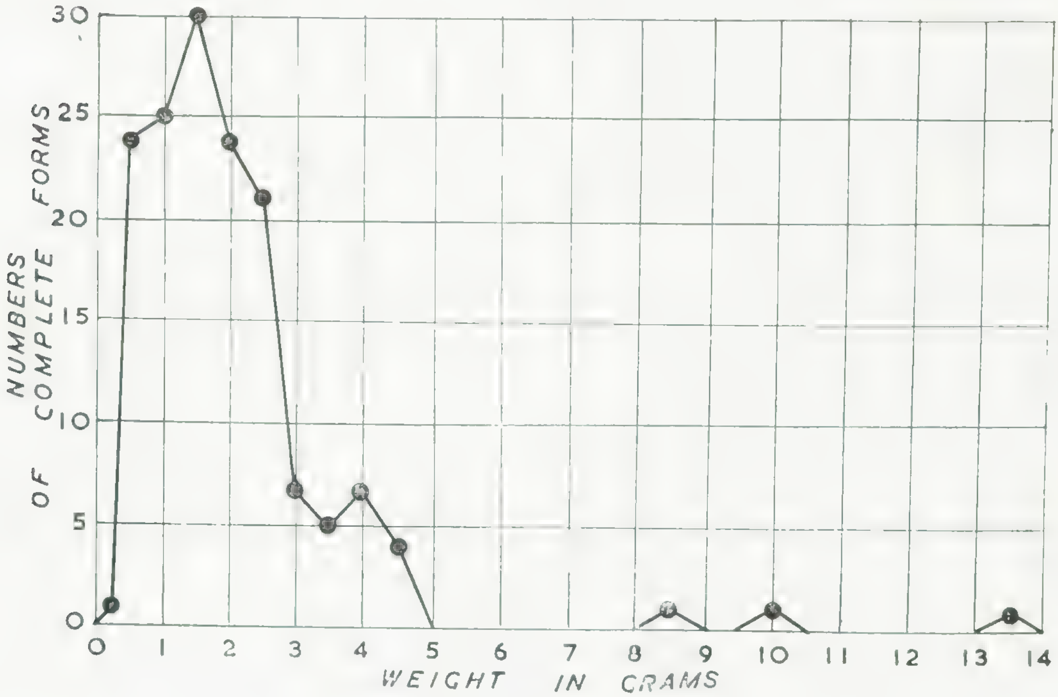


FIGURE 7.

Frequency polygon illustrating numbers of complete australites with similar weight values, Nirranda Strewnfield.

The frequency polygon (text figure 7) reveals that the greatest number (125 or 81 per cent.) of complete and nearly complete australites from the Nirranda Strewnfield occur in the lower weight range, between 0·5 and 2·5 grams, with a prominent mode at 1·5 grams. Three specimens weighing 15·5, 19·5 and 55 grams respectively have been omitted from the frequency polygon for convenience of representation. There is

a marked gap in the frequency polygon created by a complete absence of specimens in the 4·5 to 8·5 grams weight range, while there are no complete forms weighing less than 0·25 grams.

The calculated average weight of 2·56 grams (Table V) for the Nirranda Strewnfield australites is strongly influenced by the inclusion of 6 specimens weighing from 8·5 to 55 grams. If these are omitted, the calculated average weight is 1·5 grams, a value which then agrees with the mode of the weight–numbers frequency polygon (text figure 7).

Specific Gravity.

Specific gravity values of the Nirranda Strewnfield australites have been determined to the nearest third decimal place, but they have been plotted in the accompanying frequency polygons to the nearest second decimal place.

The lowest specific gravity value is 2·363 for a core fragment (reg. no. E771) weighing 0·825 grams, and the highest is 2·474 for a lens (reg. no. E1015) measuring 11 mm. in diameter and 5·5 mm. in depth, and weighing 0·772 grams. The calculated average specific gravity value for the 366 specimens is 2·409.

That the specific gravity can vary a little in one and the same australite, is indicated by a specimen of an oval-shaped form (reg. no. E836) that was discovered in three pieces lying in contact, partially embedded in soil. Determinations of specific gravity values for the three pieces separately, and for the three together, are shown with their respective weights thus:

	Weight in Grams.	Specific Gravity.
Whole form	4·436	2·395
Complete flange	0·762	2·410
First half of core	1·886	2·395
Second half of core	1·788	2·394
Two halves of core together	3·674	2·395

Flanges normally have a rather lower specific gravity than body portions of australites (cf. Baker and Forster, 1943, p. 383, and Table 5, p. 384), but this particular oval-shaped form is an exception in having a flange with a significantly greater specific gravity than the body portion. The determination for the complete flange was checked and re-checked, but always with the same result.

In contrast to this specimen, a button fragment (reg. no. E1029) from which the attached flange remnant was broken away, showed the same specific gravity values for flange and for body portion—

	Weight in Grams.	Specific Gravity.
Button fragment with flange attached ..	1·926	2·392
Core portion	1·767	2·392
lange portion	0·159	2·392

The relationships of specific gravity to total numbers of specimens and to the total weights of australite glass having the same specific gravity, are shown in text figure 8.

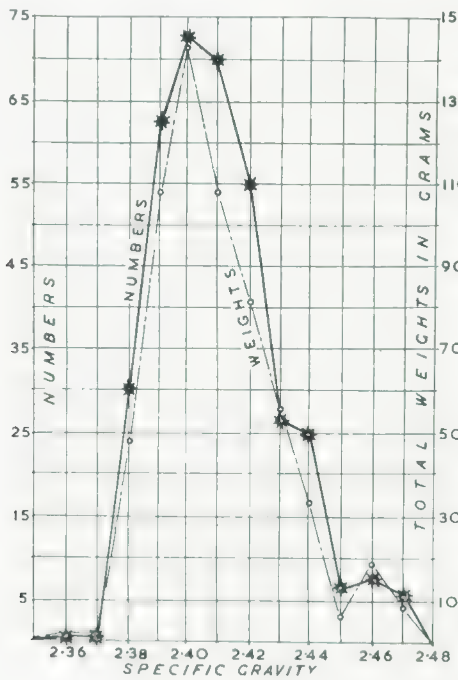


FIGURE 8.

Frequency polygons showing relationships of numbers of specimens and weights of specimens to specific gravity values for Nirranda Strewnfield australites.

The two frequency polygons in text figure 8 show a close parallelism throughout, and a relatively regular increase in numbers of specimens and in weights from the 2·37 specific

gravity value to the mode of 2·40, after which there is a steady decline to 2·47, but for a minor peak at 2·46. One specimen weighing 55 grams, with a specific gravity value of 2·44, has been omitted from the total weights–specific gravity frequency polygon; its inclusion would produce a very prominent peak rising to nearly 90 on the 2·44 specific gravity co-ordinate in the weight frequency polygon.

Analysis of the numbers–specific gravity frequency polygon (see text figure 8) by the construction of separate frequency polygons for the different shape groups (see text figures 9 to 11), reveals that it is compounded of populations possessing variously

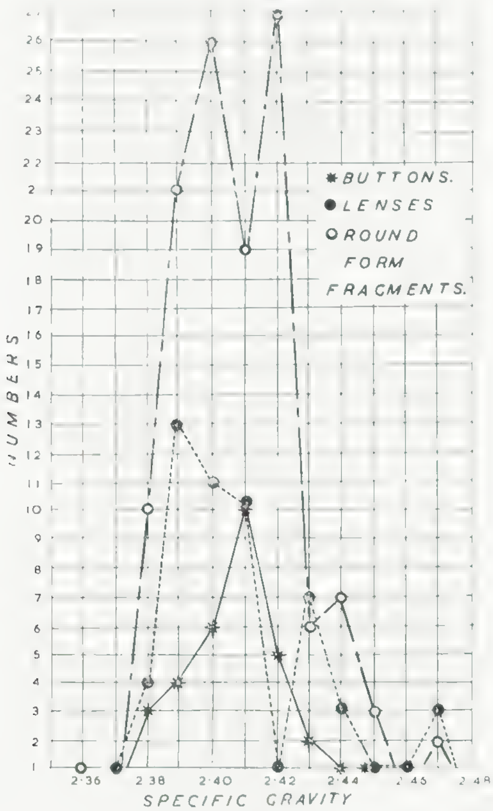


FIGURE 9.

Frequency polygons showing the relationships of numbers to specific gravity values of buttons, lenses and round-form fragments among the Nirranda Strewnfield australites.

situated modes, indicating specific gravity variations from shape group to shape group. In the overall frequency polygon (text figure 8), however, most irregularities, which in themselves are significant, have been smoothed out.

The relationships of numbers of specimens to specific gravities for the round-forms of australites, including round-form fragments, are set out in text figure 9; round cores are not shown because of low numbers (only 4 specimens).

Features of the frequency polygons for the round-forms of australites (text figure 9) are—(i) the more or less regular increase from 2·38 to a mode of 2·41 for button-shaped forms, and a regular decrease thereafter to 2·44, (ii) the existence of two modes (at 2·39 and 2·43) in the frequency polygon for the lens-shaped forms, and a distinct shortage of specimens having a specific gravity of 2·42, (iii) two prominent peaks (at 2·40 and 2·42) in the frequency polygon for round-form fragments, with a marked fall in the 2·41 region and comparatively high numbers of specimens in the 2·39 region; this reflects the original character of the complete forms from which the fragments were developed—some coming from buttons and some from lenses—but there are interesting discrepancies such as (*a*) the occurrence

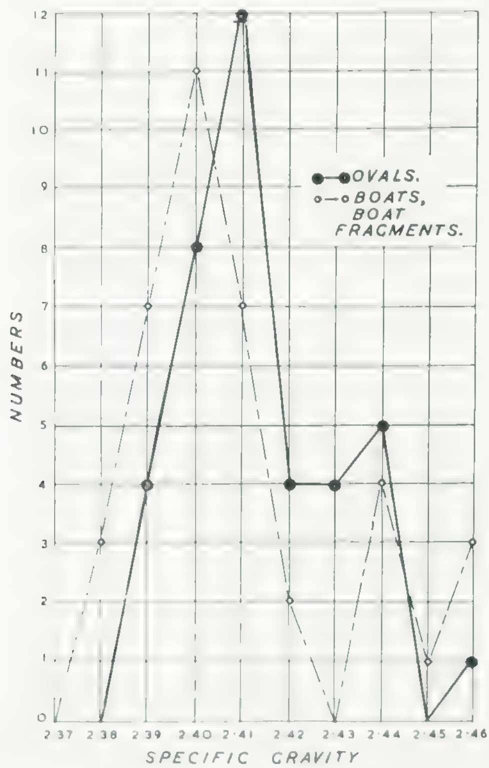


FIGURE 10.

Frequency polygons showing the relationships of numbers of specimens to specific gravity values of oval-shaped forms, and of boat-shaped forms and fragments therefrom, among the Nirranda Strewnfield australites.

of a depression in the round-form fragment polygon on the 2·41 specific gravity value, which is the value of the mode for button-shaped specimens, and (*b*) the occurrence of a peak on the 2·42 specific gravity value, which is a value for which there are relatively low numbers of buttons and even fewer lenses.

Among the elongated forms of australites, the numbers—specific gravity frequency polygons (text figure 10) reveal modes of 2·41 and 2·40 for oval-shaped and boat-shaped australites respectively, the mode for the oval-shaped forms agreeing with that for button-shaped forms. Both of these elongate shape groups show a shortage in numbers of specimens with a specific gravity value of 2·43, and minor peaks at 2·44. The reason for this is obscure, if not a result of sampling.

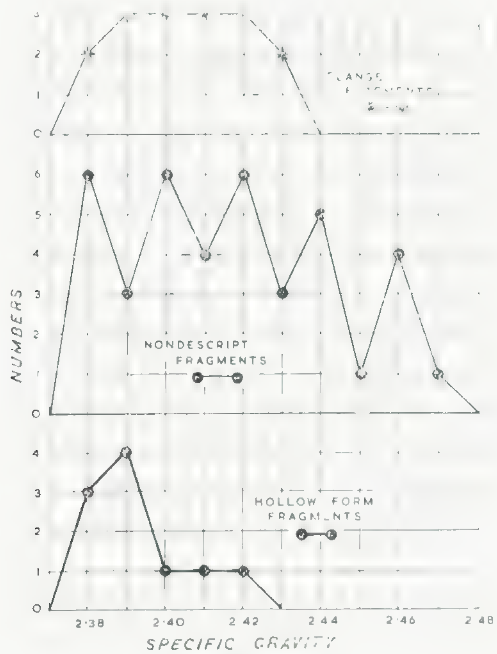


FIGURE 11.

Frequency polygons showing relationships of number of specimens to specific gravity values for flange fragments, nondescript fragments and hollow-form fragments among the Nirranda Strewnfield australites.

Frequency polygons have not been constructed for the groups of elongated australites referred to as dumb-bells, as canoes, and as teardrops, because of low populations of specimens in each of these shape groups. Numbers are a little higher in the group of the fragments which embraces flange fragments, nondescript fragments and hollow-form fragments as distinct groupings from those (round-form and elongate-form fragments) already

plotted in text figures 9 and 10. Although they have no especial statistical significance, the numbers—specific gravity relationships of these three separate groups of fragments are shown in individual frequency polygons (text figure 11) for purposes of record.

The absence of a mode in the frequency polygon for flange fragments (text figure 11) is probably due to low numbers, while the serrated character of the frequency polygon for nondescript fragments seems to be partly a result of derivation of these fragments from several of the australite shape groups. Seventy per cent. of the hollow-form fragments occur in the 2·38 to 2·39 specific gravity range, indicating that hollow forms generally have lower specific gravity values than most members of the other australite shape groups. This is not entirely a consequence of their gas content, because the fragments of the hollow forms are themselves relatively free of included gas bubbles.

Compared with similarly constructed frequency polygons for the specific gravity values of 555 Port Campbell australites (see Baker and Forster, 1943, pp. 389-390), and for the weight distribution of complete australites from Port Campbell and other localities (Baker and Forster, 1943, p. 393), the Nirranda Strewnfield australites show similar relationships. For the weights polygon the mode in each occurs at 1·50 grams, and there is a comparable distribution on the left-hand side of each mode, and a comparable distribution on the right-hand side of

TABLE VI.

Strewnfield	Number of Specimens Found.	Number of Specific Gravity Determinations.	Average Specific Gravity for all Values Determined.	Range of Specific Gravity for all Values Determined.	Average Specific Gravity of Complete Forms.	Range of Specific Gravity of Complete Forms.
Nirranda ..	370	366	2·409	2·363 to 2·474	2·410 (155 spp.)	2·37 to 2·47
Port Campbell	1,487	573	2·397	2·305 to 2·465	2·404 (233 spp.)	2·33 to 2·47
Moonlight Head	20	15	2·411	2·400 to 2·435	2·415 (9 spp.)	2·40 to 2·44

each mode. The frequency polygons for the relationships between specific gravity and total number of specimens for each strewnfield are also generally similar, while there are a few minor variations among the specific gravity polygons for similar shape groups from each strewnfield.

Relationships between the specific gravity values of the Nirranda, Port Campbell and Moonlight Head Strewnfields australites are shown in Table VI.

Fracture and Fragmentation

The glassy nature of australites makes them liable to ready fracture, and 58 per cent. of the Nirranda Strewnfield australites are fracture fragments. The means whereby any particular australite has been fractured is uncertain, but some of the possibilities are (i) fracture by impact on landing, (ii) fracture due to impact by other objects displaced during surface run-off across the exposed areas on which the australites were found, (iii) fracture resulting from diurnal temperature changes, (iv) fracture during usage by aborigines, and (v) fracture or wear in the gizzards of large native birds (emus and bush turkeys).

Unweathered fracture surfaces typically tend to be conchoidal, with a marked ripple fracture on the curved surfaces. Conchoidal fracturing produces curved segments from the equatorial regions of the australites, and these segments sometimes possess still-attached flange remnants, sometimes show a flange band, and sometimes show neither of these features, according to the shape group from which they were derived, or according to the degree of abrasion suffered by an originally flanged fragment.

The result of the fracturing process is to produce various kinds of fragments of different size and shape, both from one and the same, and from different australite shape groups. Most fragments retain sufficient shape and structure to indicate the particular shape group from which they were derived, but a few are classified as nondescript because, although they may retain recognizable remnants of anterior surface, of posterior surface, or of equatorial regions occasionally with flange remnants, they provide no clear indication of original shape. Many nondescript fragments have been derived from the interiors of the body portions of australites, and thus cannot be classified with any particular shape group since internal structures alone do not serve to discriminate one shape group from another.

The type of fracturing occurring in some australites is depicted in text figure 12.

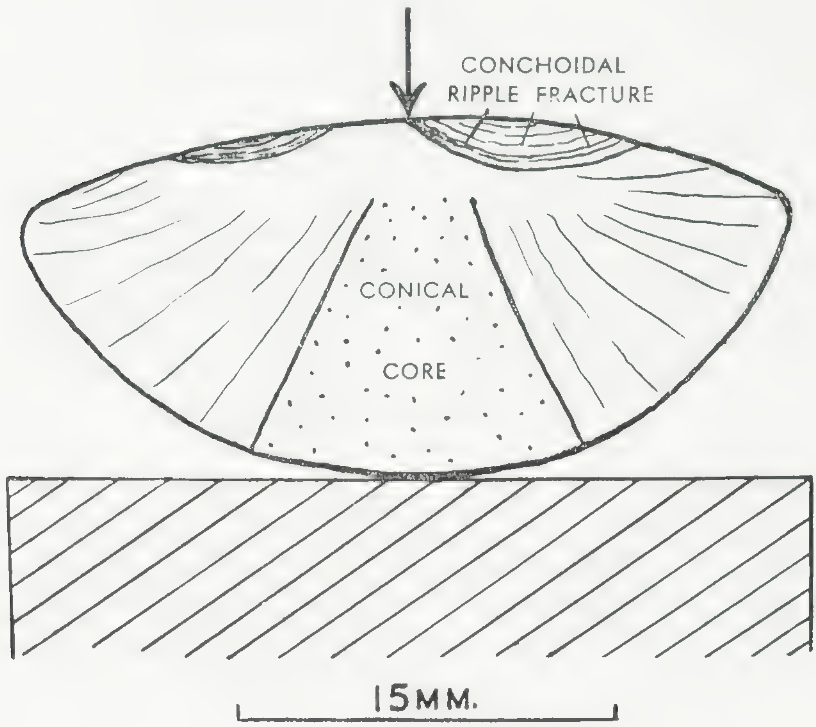


FIGURE 12.

Sketch diagram illustrating the principal types of fracture in australites.

With the posterior surface of the australite in contact with a small steel anvil, repeated light blows in the front polar region of the anterior surface yielded chips showing conchoidal and ripple fracture. With sharper blows, a conical-shaped core was ultimately produced, having a greater proportion of posterior surface than of anterior surface, and thus closely resembling the naturally occurring conical cores (see Plate III, figure 14). This suggests that the glass of the secondarily formed anterior surfaces in australites is rather less mechanically stable than that of posterior surfaces. Moreover, since 87·5 per cent. of specimens were found to have their anterior surfaces upwards, the anterior surfaces are thus more exposed to subaerial weathering agents, once the australites have been uncovered from their soil environment. Anterior surfaces also receive a greater proportion of direct sunlight, and since the coefficient of thermal conductivity of australites is low, between

that of Darwin Glass (0·002) and that of artificial glass (0·0005 cals./cm./°C.), rate of heat transference is therefore low, and so the exposed anterior surfaces should be more liable than posterior surfaces to cracking by repeated expansion and contraction.

Several stages in the development of fragmentation products by a process of natural flaking and fracturing have been noted among the Nirranda Strewnfield australites. The onset of fracturing is marked in some specimens by the appearance of fine, hair-like cracks (cf. Plate I., figure 7). These become gradually widened and deepened, partly by etching, and in time deep, more or less parallel-sided grooves result (cf. Plate I, figure 8, and Plate IV, figure 21). The grooves occasionally form a crudely radial pattern on the anterior surface, as shown in Plate II, figure 9. Sometimes they curve around from anterior to posterior surfaces (Plate IV, figure 21) and sometimes they tend to be parallel with the equatorial periphery (see right-hand side of Plate II, figure 10). In course of time, pieces of australites delineated by prominent grooves become fractured from the parent form, largely as a consequence of strains and stresses set up by expansion and contraction caused by diurnal changes of temperature. Since most of the Nirranda Strewnfield australites were located on barren patches, they have been extensively exposed to the full force of the sun's rays during the daytime, and remained unprotected from the lower temperatures prevailing at night-time. Repeated expansion and contraction could therefore well have been responsible for partial fracturing of the australites that possess strongly-marked, relatively deep grooves; such a process seems to have occurred with some australite specimens. The process is further aided by the lodgment of clay and fine sand grains (mainly quartz) in the grooves, accompanied by continued etching. The forces exerted by differential expansion between the material in the grooves and the adjoining australite glass would ultimately lead to fracturing away of any portions outlined by grooves. Similarly, clay and fine sand are sometimes wedged and/or cemented into bubble pits.

The importance of the existence of strain lines in australite glass as a factor contributing to their fragmentation, once they became exposed to atmospheric agencies, receives support from Hammond's (1950, p. 272) work on the compressive and tensional strains in non-homogeneous glass. Hammond has shown that

even a scratch on the surface of highly strained glass may cause disintegration. The glass of australites is not in a state of high strain, but that the glass is not completely homogeneous and is under some strain is proved by the fact that all forms are completely flow-lined, with certain of the flow-lined areas exhibiting weak birefringence and undulose extinction under the petrological microscope. Opportunities for scratching to initiate fragmentation are plentiful on the wind-swept, rain-washed sandy portions of australite-bearing patches of ground.

The breaking away of flanges, rarely as complete entities (Plate I, figures 4 and 5), more frequently as small pieces, is one of the most common features of australite fragmentation. Fracturing here is largely brought about as a direct result of differential expansion of clay particles and sand grains wedged in the narrow gap separating the equatorial peripheries of the posterior surfaces of australites from the partially overhanging neck surface (cf. text figure 15) of the flanges. The process of flange separation by fracturing is assisted by the fact that the planes of union between the flange and body portions of australites are the least mechanically stable of all australite structures, for here the glass is thin, and often a position where etching processes have been active.

The fracture and fragmentation of hollow forms of australites, and the development of the flaked equatorial zones on the larger cores, have been referred to earlier.

Sculpture Patterns and Etching Effects

The sculpture patterns of the Nirranda Strewnfield australites consist of varying combinations of flow lines, flow ridges, grooves, small bubble pits and larger bubble craters. These features are not as well shown as on the majority of the Port Campbell australites, because of more marked destruction by abrasion. Internal structures, however, show equally as complex flow-line patterns, as can be seen from the photographs of two thin sections of lens-shaped australites (Plate V, figures 26 and 27), and as shown on the walls of deeper grooves that are better protected from abrasion but exposed to etching solutions.

It has not yet been conclusively proved whether the external sculpture of tektites is a primary feature generated prior to and/or during atmospheric flight, or whether it is entirely a secondary feature brought about by natural etching, by soil

solutions. As observed on the external surfaces of Australian tektites, it seems that sculpture patterns are manifestations of internal structures, and are at least accentuated by natural etching under certain conditions, practically destroyed by abrasion under other conditions. The appearance of an australite at the time of its discovery thus depends upon whether etching processes or abrasion had been dominant. There is no doubt, however, that the sculpture patterns observed on the external surfaces of australites and fracture fragments of australites depend upon the nature of their flow-lined interiors. This is proved by the following observations—(i) when they are artificially fractured, australites show highly vitreous, relatively smooth, convex and concave surfaces, occasionally with a subsidiary ripple fracture pattern, (ii) naturally fractured surfaces of some antiquity frequently show flow-line patterns and pits, and all have lost their vitreous lustre, (iii) when dull, abraded australites are etched in the laboratory, a sculpture pattern composed of flow lines, pits and shallow grooves is very well brought out, according to the time of immersion and the strength of the etching solution. At the same time, the dulled surface becomes increasingly lustrous, although never as highly vitreous nor as evenly smooth in appearance as freshly fractured surfaces.

Artificial etching tests have yielded some interesting results. An oval-shaped australite (Plate IV, figures 24 and 25) from the Nirranda Strewnfield, had, when first discovered, dulled and smoothly worn external surfaces. It showed occasional ill-defined shallow pits and worn down flow ridges on the anterior surface, and poorly marked bubble pits and flow grooves on the posterior surface. The glass between these sculpture elements showed a very minute pitting as revealed under a x10 hand lens. This specimen was immersed in 4 per cent. hydrofluoric acid at 21·8°C. for 64½ hours, in such a way that all of the anterior surface and half of the posterior surface were immersed. After 64½ hours, the temperature measured 20·5°C., and after washing and drying the specimen, re-weighing revealed a loss in weight of 0·397 grams. If the concentration of the hydrofluoric acid did not vary appreciably during this period, the australite glass dissolved at an approximate rate of 0·006 grams per hour. The non-immersed portions of the specimen remained virtually unaffected, except for slight attack by acid fumes. This portion thus still shows the dull, abraded surface that was evident all

over the specimen when it was discovered on the ground. On the immersed portion, however, the former dull character has vanished, and the specimen appears fresh and new (Plate IV, figures 24 and 25). Etching occurred differentially along flow line directions, bringing out the sculpture pattern particularly well. Deeper etching along some flow line directions produced rather deeper flow channels. Closer examination of these channels reveals that some have a vermicular segmented appearance as though composed of strings of small bubble depressions in contact. Other etching effects are the accentuation and deepening of certain bubble pits.

The fact that minor amounts of differential etching occurred in the hydrofluoric acid points to slight variations in composition along flow line directions. Presumably somewhat deeper etching was directed along streaks of australite glass richer in silica, showing that flow-lined australites are not entirely composed of strictly homogeneous glass. In the initial phase of the formation of australite glass there has therefore not been complete and thorough mixing of the original ingredients, suggesting rapid fusion at relatively high temperatures, followed by rapid cooling. In the etch test described above, it has not been possible to detect whether one or the other of the anterior or posterior surfaces respectively became more deeply etched. The eye cannot detect any significantly marked attack of greater degree on one surface more than on the other, even with the aid of a hand lens. It would thus appear that little, if any, chemical variations exist between anterior and posterior surfaces respectively, although there may be physical differences, inasmuch as it is suspected from other evidence (cf. Fenner, 1935, p. 132) that the glass near and at the anterior surface, and the glass of the flange, may be rather less mechanically stable than the glass composing the rest of the australite.

Evidently natural etching only affects those australites that occur in positions favourably situated for attack by weak acidic solutions, enabled to act over a period embracing the last few thousand years of Recent geological time. Such favourable positions require burial in soils or other surficial materials where etching solutions were available. Australite specimens displaying accentuated sculpture patterns on discovery evidently have been recently released from their soil environment, while those with poorly marked sculpture patterns, or none at all, were released long ago, and in the meantime have been exposed to the action of various abrasive agents.

Bubble Pits.

Etching experiments with australite glass, using 4 per cent. hydrofluoric acid, have shown that the smaller pits can be initiated and accentuated on the worn external surfaces of australites. They develop above tubes of glass of slightly more acidic composition, such tubes of glass being evident in thin sections of australites by virtue of slight differences in refractive index values, compared to neighbouring parts of australite glass. The etch pits so produced tend to resemble some of the smaller depressions that have become regarded as the impressions left by the escape of very small gas bubbles on the primary surfaces of australites, and which are now preserved on posterior surfaces only, provided those surfaces have not been unduly weathered.

The larger circular to oval-shaped depressions on posterior surfaces of the body portions of australites (cf. Plate I, figures 2 and 6, Plate III, figure 12) are accepted herein as representing positions of gas bubble escape, and from a study of their radii and arcs of curvature (see later) the posterior surfaces are considered to be remnant portions of the original primary forms of australites. The presence of bubble pits on the original surfaces of these primary forms would point to high temperatures of formation, and possibly some boiling at the surface.

Bubble pits are seldom encountered upon the posterior surfaces of flanges, but minute etch pits are present (Plate I, figure 2). Bubble pits are also infrequent features of anterior surfaces generally, so that they are thus relatively uncommon upon all of the structures of australites that have had a secondary origin. The bubble pits that do appear occasionally on anterior surfaces could well represent internal bubbles (sometimes seen in thin sections) that have become exposed at the surface on the particular levels to which a process of sheet fusion and ablation had progressed (cf. Baker, 1944, Plate I, figure 4). This suggestion receives support from the observation that some such bubble pits reveal evidence of inward collapse against pressure. They sometimes show inrolling of the upper edges of the collapsed bubble pit walls, under the influence of the secondary phase of melting of thin surface films and other processes responsible for the formation of anterior surfaces. More open pits in this category sometimes show a small pyramid of glass at the bottom of the collapsed bubble pit.

Flow Ridges.

Flow ridges (Plate I, figures 1 and 8, Plate IV, figure 19) are characteristic of the anterior surfaces (i.e. front or forwardly directed during flight) of australites. In fact they are invariably confined to the anterior surfaces of the body portions and the flange portions, where flanges are still present. Their distribution is remarkably regular over the major portion of the anterior surface of any particular australite, but their shape and distribution vary a little in the different australite shape groups where flow ridges are developed, variation being according to the particular forms upon which they have been generated. The spacing apart of the flow ridges varies from 2 to 4 mm., but the distance from crest to crest across the intervening shallow troughs is more usually approximately 3 mm.

The smaller forms of lens-shaped australites (Plate I, figure 3) seldom have flow ridges preserved, larger forms such as "bungs" and large cores (Plate III) evidently did not develop flow ridges. It is therefore only on forms of intermediate size that flow ridges are to be observed—forms such as the buttons, the larger of the lenses, the ovals, and some of the boats, canoes, teardrops and dumb-bells. This indicates that there is an optimum size requisite for flow ridge development. Forms without flow ridges in the shape groups where flow ridges are a characteristic feature of anterior surfaces have had them obliterated by weathering upon the earth's surface.

Among the Nirranda Strewnfield australites are 100 complete or nearly complete forms (i.e. 37 per cent. of the total number discovered) that reveal the flow ridges in a sufficiently preserved state for their character to be determined. Several fragments from this strewnfield show parts of flow ridges on their broken anterior surfaces, but there is never enough preserved to decide whether the complete flow ridges were originally concentric or spiral in arrangement.

Concentric (Plate I, figure 8) and spirally arranged flow ridges are present on the Nirranda Strewnfield australites in the proportions shown in Table VII. Some of the spiral flow ridges are arranged in a clockwise fashion, others are counter-clockwise (Plate I, figure 1).

In comparison with the percentage shown in Table VII, Fenner (1934, p. 74) found that of 75 buttons selected at random from the Shaw Collection, 42 (i.e. 56 per cent.) had concentric flow ridges, while 18 (24 per cent.) were anticlockwise spiral, and 15 (20 per cent.) were clockwise spiral.

In addition to the main types listed in Table VII, an unusual and rare variety of flow ridge is crudely radially arranged on a large fragment from a hollow form (E830).

TABLE VII.

Flow Ridge Arrangement.	Per cent.
Concentric	46
Anti-clockwise spiral	27
Clockwise spiral	27
Double spiral	1 specimen

Normally the spiral flow ridges commence near the front poles of the anterior surfaces, and continue more or less uninterruptedly until they merge into the equatorial periphery of the specimens (text figures 13B and 13C). Generally there is thus one continuous ridge on each of the australites having spiral flow ridges. One specimen (E887) among the Nirranda Strewnfield australites, however, is unusual in possessing two open spiral ridges (text figure 13D) arranged in a manner simulating the two arms of certain spiral nebulae.

The number of concentric flow ridges on australites is a little variable. Some of the very small lenses are fundamentally too small to show flow ridges, slightly larger specimens may have one concentric flow ridge only. Larger lenses and most button-shaped australites, also several oval-shaped forms of comparable size, generally have two or three, sometimes four, concentric flow ridges. Occasionally the outermost flow ridge coincides with the rim of forms that do not possess flanges. In the larger of the flanged button- and oval-shaped australites, the existence of a greater number of flow ridges than usual is indicated by the complex merging and interlacing of several ridges in the equatorial regions, principally on and near the anterior surfaces of the attached flanges, where complicated wavy flow-ridge patterns have been generated. Sectional aspects of such specimens (cf. Plate VI, figure 28) reveal the presence of five or six, sometimes seven, flow ridges for the form as a whole. Spiral flow ridges do not show such marked crenulation on reaching the equatorial peripheries.

A few (6 per cent.) of the button-, lens- and oval-shaped australites are similarly finely pitted on both the anterior and the posterior surfaces. They show no flow ridges characteristic of anterior surfaces, and none of the bubble pits that typify posterior surfaces, hence, unless a flange, flange remnants or flange band are present, it becomes impossible to detect which is the posterior and which the anterior surface. In view of the fact that the pitting is of a very fine character, and very unlike that of normally bubble-pitted surfaces, it seems that such "two-surface pitting" arises as an effect of rather extensive weathering and etching, rather than being the result of the action of agencies operating during the phase of atmospheric flight.

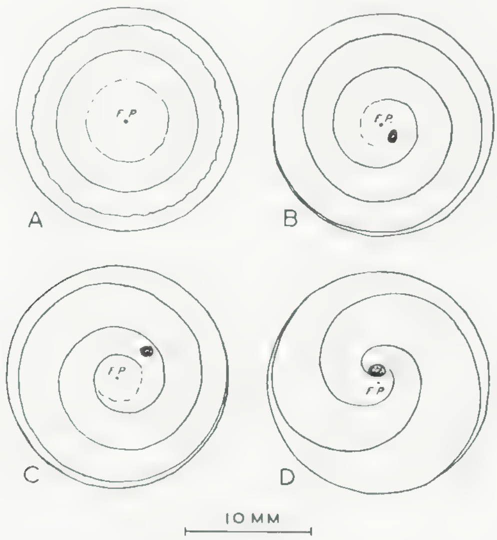


FIGURE 13.

Diagrammatic representation of flow ridges on the anterior surfaces of australites that are circular in plan aspect.

A — concentric flow ridges; B — spiral clockwise flow ridge; C — spiral anti-clockwise flow ridge; D — double spiral flow ridges.

(F.P. indicates the front polar regions of each anterior surface. The small dark, oval-shaped areas in figures B, C and D represent etch pits.)

In text figure 13A, the flow ridge nearest the front pole of the australite is sometimes sharply marked, but often ill-defined due to subsequent erosion. The outermost flow ridge depicted is shown as being somewhat "crinkled" to indicate the onset of the development of a wavy character brought about by several flow ridges running into one another near the equatorial periphery. The intermediate flow ridge shown in figure 13A is most frequently the best defined, largely because of less abrasion in its vicinity.

Regarded from the front polar regions, outwards towards the equatorial limits of these flow-ridged australites, the spiral flow ridges can be pictured as descending helical spirals, the apex of which is at the front pole, the spiral broadening out towards the equatorial edge of the specimens, and the respective heights of such spirals being equivalent to the distance between the front pole and the radical line* of each australite possessing flow ridges of this nature. Heights of spiral flow ridges are thus equivalent to the lengths OM shown in text figure 19.

Few, if any, of the spiral flow ridges commence as sharply marked ridges right at the front pole position of each australite possessing a spiral flow ridge (cf. Plate I, figure 1). They are often initiated from one side or the other, rarely from both sides, of an elongated etch pit situated within the front polar region (cf. text figures 13B and 13D). The development of the spiral character of flow ridges on these forms can be partly accredited to the presence and position of such pits, for they evidently affect the smooth and regular flow wave motions generated in thin films of plastic australite glass moving away under frontal pressure from front polar to equatorial regions, at any particular stage of a process involving sheet fusion of australite glass. It is difficult to assess exactly what effects variations in boundary layer flow of the air in contact with the fast-moving australites may have had upon such surface features as the flow ridges. No doubt they were partly responsible for their development, and it seems probable that the character and changing nature of front surfaces, which alter as the arc of curvature of the forward surface varies with degree of ablation, would have marked effects upon variation in boundary layer flow, and this would be reflected in the position and migration of flow ridges. Boundary layer flow associated with drag effects operating upon the front surfaces of australites during supersonic flight, was evidently such that taken in conjunction with the development of etch pits in front polar regions, flow ridges with a spiral arrangement could be generated without necessarily assigning their origin to a process of rotation. There certainly seems to be no need to call upon rotation of australites during atmospheric flight to explain the more commonly developed concentric flow ridges, for

* The radical line is the line joining points of intersection of the two curved surfaces (constituting the posterior and anterior surfaces in australites (cf. text figures 19 and 20), and is thus a measure of the diameter of the forms, provided each circle passes through the front and back poles respectively.

they would be formed as relatively regular features during a state of maintained steady flight. Possibly some wobbling developed in forms containing spiral flow ridges; this could come about by certain buffeting effects created by turbulence in the air stream separating from the equatorial regions of such australites.

The pits that occur in the front polar regions of some flow-ridged australites (cf. text figure 13) are not necessarily all normal bubble pits. They could well be etch pits produced during atmospheric flight by the removal of slightly less stable centres of glass. Bubble pits like those on the posterior surfaces of australites are normally rare features of anterior surfaces, and where encountered, are most likely internal bubbles exposed at a particular level reached at certain stages of ablation. Forms with concentric flow ridges seldom show pits of any nature in front polar regions, although some show shallow grooves resulting from etching (possibly while on the earth's surface). Some forms with spiral flow ridges reveal no etch pits, but such may have been present in the immediately preceding stage of ablation, when the spiral ridges could have been initiated. The fact that etch pits can be readily generated and accentuated by artificial means, such as treatment in 4 per cent. hydrofluoric acid, suggests the likelihood that during ablation, certain levels are reached in the glass of the anterior surfaces of australites, where the slight inhomogeneities of certain parts lend themselves to more ready removal, forming pits. Once developed, these pits could then be partly responsible for the control of spiral flow ridge development. Under such a set of circumstances, there is reason to suppose that at various stages of anterior surface ablation, one and the same australite could have concentric flow ridges at an early stage, clockwise or anti-clockwise spiral flow ridges at a subsequent stage, and even revert again to concentric flow ridges at a still later stage. As found, the several types of flow ridges noted on anterior surfaces appear to represent the end stages of arrested flow wave phenomena, developed just prior to final consolidation of the last films of secondarily re-melted australite glass produced and forced from front polar to equatorial regions, over the surface of relatively un-heated, underlying glass. The sub-surface flow-line pattern, however, is such as to indicate that glass has been stripped from flow-trough regions more than from flow-ridge regions, in the final stages of the development of anterior surface sculpture.

The foregoing remarks apply essentially to the development of flow ridges on the anterior surfaces of australites that are circular in plan and of a suitable size and shape for their formation. The fact that the larger round forms of australites, namely the group of the round cores, do not show flow ridges, indicates that there must be an optimum, ablation-reduced size of the primary forms, at which flow ridges can be formed. This state is attained evidently after at least one half to two thirds of the glass of the primary form has been removed by ablation.

Forms of australites in other shape groups also show flow ridges, and again they are developed on examples that are smaller than the correspondingly shaped, non-flow-ridged core (and "bung") forms. Boats and canoes (Plate IV, figure 19) mainly show a tendency for the formation of concentric flow ridges, with a certain amount of flow-ridge-linkage in places, due to interference where crowding occurs near the equatorial edges of the forms.

Complete dumb-bells and teardrops among the Nirranda Strewnfield australites show no flow ridges, partly because of their small size, and partly because of destruction of such features by abrasion of somewhat larger forms. One dumb-bell fragment, representing one half of the original form, shows one concentric flow ridge constricting towards the waist region.

A study of the flow ridge variation on the anterior surfaces of certain dumb-bell-shaped australites from other south-western Victorian localities, provides substantial support for the validity of the postulate that anterior surfaces of australites as found, are secondary in development, and resulted from a process of frontal melting and ablation during a non-rotational phase of flight through the earth's atmosphere. Text figure 14 illustrates this point.

Flow ridges on the specimen from Mt. William (text figure 14, no. 1B) occur in two series that are each concentric in sense, being centred about each front pole and following the general outline of each bulbous portion of the dumb-bell-shaped form. The flow ridges become wrinkled and irregular due to mutual interference near the outer periphery of the australite. Text figure 14, no. 2B shows the type of ridges developed on dumb-bell-shaped forms that have been considerably ablated, and instead of the anterior surface being bi-polar as in text figure 14, no. 1B, the anterior portions of the bulbous ends have been removed by

ablation, and the anterior surface of the form as a whole has become mono-polar, with the single front pole now situated centrally. The flow ridges are arranged in a generally concentric manner about the front pole, but show marked angularity near the outer periphery. The sketches 1A and 2A of text figure 14 depict the side aspects of these two forms, and reveal the relationship between the disposition of the flow ridges and the nature of curvature of respective anterior surfaces.

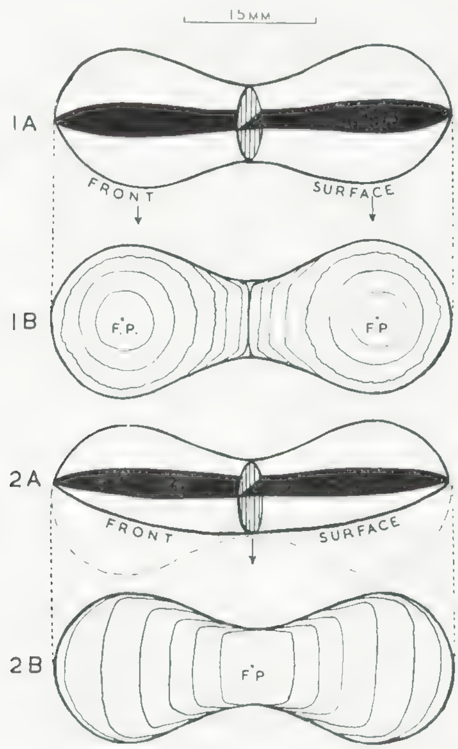


FIGURE 14.

Diagrammatic representation of flow ridges on the anterior surfaces of dumb-bell-shaped australites.

(Flanges have been omitted from the sketches).

1A—Three-dimensional side aspect of dumb-bell from Mt. William, Grampians, Victoria.

1B—Generalized plan aspect of the front surface of the form sketched in figure 1A. Based on figures 1 and 1B, Plate 5 of Dunn (1912).

2A—Three-dimensional side aspect of modified dumb-bell from Port Campbell, Victoria.

2B—Generalized plan aspect of the front surface of the form sketched in figure 2A, and based on a number of additional specimens.

The abbreviation F.P. indicates the position of the front polar regions in these australites. Arrows indicate direction of propagation through the earth's atmosphere.

Flow ridges are intimately connected with flange-building processes in australites, and added to the nature of the flow ridges, the fact that these dumb-bell-shaped forms (text figure 14) possess remnants of flanges that in each are more or less the same width in waist regions as around bulbous portions, strongly suggests the possibility that rotation was not only unnecessary, but most probably unlikely, during the phase of formation of these flow ridges and flanges.

The flow ridge patterns illustrated in text figure 14 are idealized diagrammatically; many forms of the dumb-bell-shaped australites occur in which the flow ridges are rather more irregular than illustrated, due to interference with one another, or at times, possibly due to slight inhomogeneities in the glass. Moreover, there is evidence among other examples, from the Port Campbell Strewnfield, for example, that there are several modifications of the type depicted in text figure 14, no. 2B. One such modification is that the flow ridges trend in parallel fashion away from the front polar region of one only of the original bulbous ends (cf. text figure 14, no. 1B), extending from this position transversely across the waist region and across the other bulbous portion. In such a form, the second bulbous portion is somewhat smaller and has a flatter arc of curvature for its anterior surface, thus indicating that rather greater amounts of fusion and ablation occurred in its front polar region, and that it reached a stage of relative stability before the first bulbous end. Continued frontal fusion in the polar regions of this larger bulbous end, then yielded melted glass that flowed more readily from its pole, in one direction along the length of the form and thus across the second bulbous portion, and in the diametrically opposed direction to the peripheral regions of the form.

Consideration of the side aspects of the two forms illustrated in text figure (nos. 1A and 2A), leads to the assumption that it is possible for two teardrop-shaped forms of australites to result from continued ablation in the waist regions of one dumb-bell-shaped australite. Hence all teardrop-shaped forms are not necessarily products of constriction and separation in regions of dumb-bells during rotation, as advocated by Fenner (1934, figure 2, p. 65). The evidence provided by some of the smaller teardrop-shaped australites could well be interpreted in terms of the effects of surface fusion and ablation of thin melted films on cold glassy bodies during the non-rotational end (i.e.

atmospheric) phase of the earthward flight of solid dumb-bell-shaped australites. Larger teardrops, however, provide evidence of probably having entered the earth's atmosphere as already well-developed teardrop-shaped bodies of glass, produced as such from dumb-bells during the phase of development of the primary forms as rotating, completely molten glassy bodies in an extra-terrestrial environment.

The relationship between the arrangement of flow ridges and the trends of flow lines on the anterior surfaces of the flow-ridged australites, is of considerable significance to any postulate seeking a solution as to whether or not australites rotated through the earth's atmosphere during the period when their secondarily developed anterior surfaces were under production. At the outset, this relationship is regarded herein in its simplest form, so that any minor irregularities and complexities due to interference of flow line trends, such as slight inhomogeneities in the glass itself, or the encountering of small internal bubbles at various levels of the ablation process, have been purposely overlooked in making generalizations concerning the relationships between flow ridges and flow lines on anterior surfaces. It can be observed on the anterior surfaces of many australites (e.g. E755, E760, E836, E837, E926, E971, E1025, E1040), that such fine flow lines as are present, cut right across the flow ridges without any displacement in trend, no matter whether the flow ridges are concentric or spiral. These fine flow lines mainly arise in the front polar regions of anterior surfaces, and tend to radiate out towards the equatorial edge of each form. The flow lines are thus at right angles to the flow ridges on the curved anterior surfaces; they are never parallel with them, nor do they anywhere appear obliquely tangential to the flow ridges. If rotation had occurred during the period of formation of the flow ridges, then the flow lines, more particularly than the flow ridges, would be expected to show spiral trends. None of the flow line patterns on anterior surfaces show any tendency whatsoever to be spiral in arrangement. This fact provides an additional pointer to the probability that australites did not of necessity rotate throughout the whole period of their transit through the earth's atmosphere. The formation of flow ridges and associated radial flow line trends, and the intimate connection between flow ridges and flange-building processes, thus seem to be manifestations of the nature of the movement of thin films of secondarily melted glass

under the influence of frontal pressure and drag, acting on the outwardly curved forward surfaces of non-rotating bodies of australite glass.

Flow Lines.

The flow-line directions of australite glass are made evident on the surfaces of different forms by the presence of fine, narrow, thread-like streaks and channels, in most parts accentuated by natural etching. Flow-line patterns also become well-marked on naturally etched fracture fragments of australites. In thin sections of australites, the flow lines are pronounced under certain conditions of lighting, as long, slender streaks of glass which have slightly different refractive index values to neighbouring glass, and in parts show strain polarization.

The patterns formed by the flow lines are variable and remarkably complex within the body portions of australites (Plate V, figures 26 and 27). Within the flanges, they are usually arranged in spiral fashion (see Baker, 1944, Plates I to III), and often show puckered complications in the chin regions due to the jamming and contortion of warmer glass moving in against cooler glass (cf. Baker, 1944, Plate II, figures 2, 3, 5, 6 and 7). Some of these flow-line patterns in flanges are quite clearly defined on several naturally etched flange fragments from the Nirranda Strewnfield.

On the external surfaces of non-fractured australites, flow-line directions trend radially outwards from the front pole on anterior surfaces. They are concentric on the posterior surfaces of flanges (cf. text figure 15), and also on the neck surfaces of flanges, where they represent the outcrops of the internal spiral and puckered flow lines. Flow lines are not characteristic features of the posterior surfaces of body portions, unless abrasion, followed by prolonged natural etching, has removed the outer primary surface and thus exposed lower layers of the interior. Flow-line patterns generated in this way usually reveal the complexity of the internal flow-line structures. A few of the Nirranda Strewnfield australites (e.g. reg. no. E1022), like certain australites from other strewnfields, possess occasional smoother, non-pitted, circular to ovate swirls that reveal irregular spiral flow-lining (Plate III, figure 15). These swirls are surrounded by the characteristically bubble-pitted regions of posterior surfaces. They are evidently areas of the primary surface that escaped boiling or gas accumulation, and probably represent rather more viscous portions of molten glass that became swirled about in a quite local vortex motion.

The internal flow-line pattern of an australite button is shown diagrammatically in text figure 15, in order to bring out the relationship of the complexities of the interior compared with the more simplified patterns on the outside surface. Portion of the posterior and neck surfaces of the flange have been included to show these relationships for the flange in particular. The terms " chin," " neck " and " seat " employed in text figure 15, have been described elsewhere (Baker, 1944, p. 8).

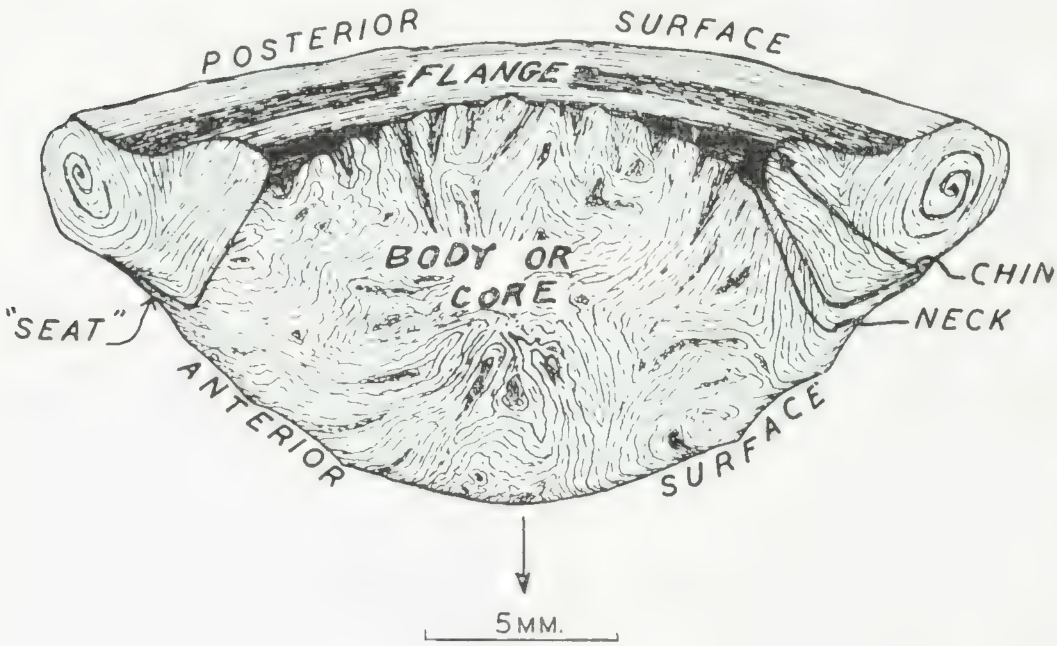


FIGURE 15.

Diagrammatic representation of a vertical section taken between the polar plane and the equatorial region of a flanged australite button. Arrow indicates direction of propagation through the earth's atmosphere.

The complex character of the primary internal flow structures is indicated in the body or core portion in text figure 15, and shown in greater detail in Plate VI, figure 28. There is a tendency on the posterior portion of the body for flow lines to indicate streaming towards the bases of bubble pits, whereas the complex internal flow-line pattern is frequently cut off abruptly by the secondarily developed flow lines and flow troughs of the anterior surface portions. The outermost thin film of australite glass on the anterior surface, shows a trend

of secondary flow lines away from the front polar regions towards equatorial regions where the flange is built up; this trend of flow lines is best observed in the partially ablated "seat" regions.

A most characteristic and significant feature of the internal flow lines of the flange is the generally coiled or spiral pattern. The outcrops of these flow lines on the posterior and neck surfaces of the flange, generally provide concentric flow-line patterns, irrespective of shape group, so that these external flow lines are parallel to the outer (and inner) edges of flanges, which themselves are parallel to the outline of the form to which they are attached in any particular shape group.

The plane spiral character of the internal flow lines of any one flange is maintained all round the flange—no matter in which position a vertical radial section is made through a flange, this spiral character remains evident, with only minor variations from place to place in one and the same flange. This fact, added to the concentric nature of these flow lines on the external surfaces of the flange, indicates that the flange structures have been formed by the streaming in and over of glass secondarily melted from the front pole (i.e. from the region of the arrow in text figure 15), and forced under pressure towards equatorial regions.

Boundary layer flow in the medium (earth's atmosphere) through which the australites had a supersonic trajectory, is considered to have been partly responsible for the structures of anterior surfaces of body and flange. Where the boundary layers separated from contact with the object, at the outermost edge of the flange, turbulence was created (cf. Plate VI, figure 28), with the development of eddy currents in the low pressure region immediately behind the flange. These eddy currents are regarded as being responsible for shaping the cooling flange glass into the form we know it, and they probably account for the generally smooth nature and often slightly concave character of the posterior surfaces of flanges. Here again, it seems unnecessary to invoke rapid spinning about a vertical axis, to account for the development of these particular secondary features of australites. In fact, it is more than likely that the spirally coiled annular band of glass constituting a flange would not reveal the structures present if rotation had occurred throughout flange-building. Moreover, during rotation, liquid glass should largely have been thrown off by centrifugal forces, and thus be unavailable for extensive flange formation.

Internal flow lines constitute the major internal structures of australites (cf. Plate V, figures 26 and 27). Associated with them are less common features such as small internal bubbles, larger internal bubbles (Plate II, figure 11) and rare, minute lechatelierite particles. Where drawn-out, the lechatelierite particles contribute to the flow streaks in australite glass, and where exceedingly drawn-out, small bubbles do likewise, while the larger internal bubbles cut directly across the internal flow structures (cf. Baker, 1944, Plate I, figure 12). These features have been dealt with in some detail elsewhere (cf. Barnes, 1940, Baker, 1944), and studies of similar features in the Nirranda Strewnfield australites bear out the conclusions drawn from these earlier studies.

Grooves.

The grooves on the surfaces of australites have been referred to earlier, in connexion with the control they exert in the process of fragmentation of australites. The origin of these grooves on tektites generally has been the subject for much debate, and the deeper grooves and channels have been variously referred to in tektite literature as " bubble grooves ", " bubble tracks ", " saw-marks ", " saw-cuts ", " knife-marks ", " cannelures ", " canals ", " flow-grooves ", " gouttières ", " gutters ", " furrows ", " open channels ", and " crevasses."

The evidence for the origin of these grooves in the Nirranda Strewnfield australites points to development by natural etching along flow-line directions (i.e. mostly along lines of strain). Shallow channels are at first developed, and with progressive etching, aided by diurnal temperature changes and the effects of differential expansion and contraction of foreign materials that become lodged in these channels, occasionally resulting in the spalling away of narrow slivers of australite glass from the walls, the grooves thus become widened and deepened. These grooves are thus fundamentally " flow-grooves," inasmuch as flow-line directions in the australite glass control the positions of their initiation. Along the flow-line directions the australite glass is more siliceous, as evidenced from optical characteristics, and hence it is more readily dissolved out by the etching solutions in soils. Occasionally, the flow-line directions are marked by associated strings of small bubbles; these would provide sites for the lodgment of small quantities of etching solutions, and

the resulting grooves have a segmented appearance. A few grooves seem to have been single bubbles, now drawn-out into very long slender shapes; such types are more typical of the "tails" of teardrop-shaped australites.

Not all the grooves on the surfaces of australites follow flow-line directions. Some represent the positions of original fine fracture lines that cut right across flow-line directions, and have evidently been deepened and widened by etching; flow-line patterns continue on either side of such grooves, with no apparent displacement. The bottoms of most grooves are generally smooth and rounded downwards, so that in cross-sectional aspect, they are deeply U-shaped. Some of the grooves on the Nirranda Strewnfield australites, however, tend to be more or less flat at the bottom, and in rare examples they tend to be convex upwards (e.g. in reg. no. E1052).

Some of the grooves pass inwards from the exterior of certain specimens for as much as 1·5 cms., and as deeply as 0·5 mm. from the surface. Sometimes they extend superficially from the equatorial edge to the front polar regions of anterior surfaces (Plate II, figure 9), in radial fashion, and thus parallel the general directions of the radial flow lines. The fine sand and clay constituents that invariably become wedged into the grooves are sometimes loose and incoherent, but in some grooves (and occasionally in some bubble pits on posterior surfaces, and in the gap betwen flange and body of flanged forms) these constituents have become firmly cemented in place and compacted by siliceous and iron hydroxide cementing materials. The fine sand and clay constituents match those of the soils in which the australites were embedded, and so are terrestrial products in no way connected with the origin of australite glass.

OPTICAL PROPERTIES

Complete or nearly complete australites, and the larger of the fragments are pitch-black in colour, but thin fragments are translucent and brownish-green in colour when held up to a light.

The glass comprising the Nirranda Strewnfield australites, is pale yellowish-green in colour as observed in thin sections. It is practically isotropic under crossed nicols of the petrological microscope, except for minor streaks along some flow-line directions. These streaks exhibit very limited and weak

birefringence, and the fact that extinction is seen in places to be distinctly undulose, more particularly with the aid of a sensitive tint plate, indicates a certain amount of strain in parts of the glass.

No crystallites or allied bodies have been observed in thin sections under the petrological microscope, and no opaque minerals are revealed in polished surfaces examined under the reflection microscope. Apart from internal flow lines with slightly variable refractive index values compared to the rest of the glass (Plate V, figures 26 and 27), the only other features of thin sections of the glass are rare, minute gas bubbles and even more rare partially drawn-out lechatelierite particles. Only two of the Nirranda Strewnfield australites, however, were sliced for the preparation of thin sections, but these reveal little difference to some three dozen thin sections of Port Campbell Strewnfield australites, as far as colour, internal flow lines, lack of inclusions apart from lechatelierite particles, general isotropism and the presence of a few small gas bubbles are concerned.

Refractive index measurements of the glass of three Nirranda Strewnfield australites used for chemical analysis show a range from 1·511 to 1·513, compared to a range of 1·513 to 1·515 for those of three chemically analysed Port Campbell Strewnfield australites. Inasmuch as these three Nirranda examples have slightly lower refractive index values, it is to be expected from Spencer's (1939, p. 425) observations that as SiO_2 increases in natural glasses, specific gravity and refractive index decrease, then they should be a little more acidic than the Port Campbell examples. Table VIII shows these relationships between SiO_2, specific gravity and refractive index for australite glass from the two strewnfields, with SiO_2—specific gravity relationships for an analysed specimen from Peterborough added for comparison.

The Nirranda examples are more acidic than those selected for analysis from Port Campbell, and the trend noted by Spencer (1939) for other natural glasses is again evident from Table VIII, for the specific gravity and refractive index values are lower for a greater SiO_2 content. Although its refractive index value is unknown, a similar trend is indicated by the specific gravity—SiO_2 relationships for the Peterborough example, where the specific gravity is even lower for a still higher SiO_2 content. In the field, the most acidic australite

from these three localities, occurred in an intermediate position, Peterborough being approximately midway between the sites of greatest australite concentration in the Nirranda and Port Campbell Strewnfields respectively. These examples therefore

TABLE VIII.

—	Nirranda Strewnfield.	Peterborough.	Port Campbell Strewnfield.
SiO_2 content	75·90	79·51	71·62
Specific gravity in the powdered form (at 18°C.)	2·398	2·370	2·427
Refractive Index	1·511 to 1·513	*	1·513 to 1·515

* No material available for determination, and refractive index value not given in the literature (Summers, 1913).

do not show the trend of provincial distribution of australites that is evident across the Australian continent (Summers, 1909, p. 437, Baker and Forster, 1943, p. 394). However, this is not very significant in itself, when it is remembered that the three examples illustrated above are from a relatively small area only 25 miles long. Such an area constitutes but a very small portion of the vast Australian Strewnfield, where generalizations concerning provincial distribution according to chemical composition, refer to a length of some 2,000 miles across the continent, and an area of approximately 2,000,000 square miles.

CHEMICAL COMPOSITION

Approximately 5 grams of australite glass from the Stanhope's Bay locality in the Nirranda Strewnfield were chosen to include the flange portion and body portion of button-shaped australites. With this end in view, seven fragments were selected—three button core fragments, two flange fragments, one fragment representing half a button core without flange, and one button fragment with flange remnants attached. These represent registered nos. E740, E742, E765, E769, E822, E824 and E832 in the National Museum Collection, Melbourne. All the material was used in chemical analysis and refractive index determinations. The specimens were carefully freed of all extraneous foreign material prior to crushing for analysis.

For comparison, similarly selected material from the Loch Ard Gorge area, south-east of Port Campbell township, was treated in like manner. The chemical analyses were carried out by Mr. G. C. Carlos. The results are set out in Table IX, together with an earlier analysis of an australite (shape not stated) from Curdie's Inlet, Peterborough.

TABLE IX.

	1.	2.	3.
SiO_2	75·90	71·62	79·51
Al_2O_3	10·83	13·68	10·56
Fe_2O_3	1·48	0·85	0·60
FeO	4·07	4·90	3·11
MgO	1·42	2·15	1·35
CaO	2·94	3·24	1·48
Na_2O	0·92	0·98	0·91
K_2O	1·69	1·90	1·25
H_2O (+)	0·11	0·10	0·19
H_2O (−)	Nil	Nil	Nil
TiO_2	0·60	0·53	0·63
MnO	0·06	0·05	0·06
Li_2O	..	..	sl. tr.
P_2O_5	Nil	Nil	Nil
CO_2	Nil	Nil	Nil
SO_2	Nil	Nil	Nil
Cl_2	Nil	Nil	Nil
NiO	..	..	Nil
BaO	..	..	Nil
CoO	..	..	Nil
Total	100·02	100·00	99·65
Sp. Gr. powder	2·398	2·427	2·370
R.I.	1·511 to 1·513	1·513 to 1·515	..

1. Australite glass from north-east corner of Stanhope's Bay, 15 miles south-east of Warrnambool, South-western Victoria. (Anal. G. C. Carlos.)

2. Australite glass from Loch Ard Gorge district, 4½ miles south-east of Port Campbell, South-western Victoria. (Anal. G. C. Carlos.)

3. Australite glass from Curdie's Inlet, Peterborough, South-western Victoria. (Anal. G. A. Ampt, see Summers, 1913, p. 190.)

Principal variation in the australite glass analysed from the above three localities (see Table IX) in South-western Victoria, is in the silica content, that for the Nirranda Strewnfield australite glass (i.e. Stanhope's Bay analysis) being intermediate in amount to those for the Port Campbell and Peterborough examples. Total iron is a little variable, likewise the state of oxidation of the iron. Lime, magnesia, alumina and the alkalies, show little variation from example to example, while the oxides of the minor elements are equally low in the three analyses.

CURVATURE AND RELATIONSHIPS OF ANTERIOR AND POSTERIOR SURFACES

Australites have a symmetry un-matched among the various components of the several tektite strewnfields of the world, and so far little has been done to determine the nature and relationships of the curvature of their two distinct surfaces—posterior (rear) and anterior (forward) surfaces—separated from each other by flanges in certain forms (e.g. buttons, some ovals, &c.), rims in some forms (e.g. lenses) and flaked equatorial zones (Plate III, figures 13 and 16) in other forms (e.g. cores). An elementary approach is made herein to the study of the geometry of australites, in order to illustrate variability in the curvatures of the two different surfaces and to indicate their probable relationships to the primary forms from which the shapes of australites were derived.

The Nirranda Strewnfield provides a satisfactory number of australites, in a fair state of preservation, for the determination of the radii of curvature and the nature of the arcs of curvature of posterior and anterior surfaces of various forms in the different shape groups.

The results obtained from radius of curvature determinations for these two surfaces have been compared (i) one against the other (text figure 18), (ii) for the different shape groups (see Table X), and also (iii) for their relationships to diameter and depth (text figures 23 to 26 and Table XI) mainly for the round forms of australites.

Method of Obtaining Arcs and Radii of Curvature.

The method of obtaining the arcs and radii of curvature of both posterior and anterior surfaces of sufficiently well-preserved australites involved the use of silhouette tracings of

the various forms. This method was found to be quicker and more suitable than using a spherometer, because of the slight natural irregularities due to bubble pits, &c. on most of the curved posterior surfaces of australites, and to flow ridges on most curved anterior surfaces.

Each australite was mounted with plasticene on a glass slip in the manner illustrated by text figure 16.

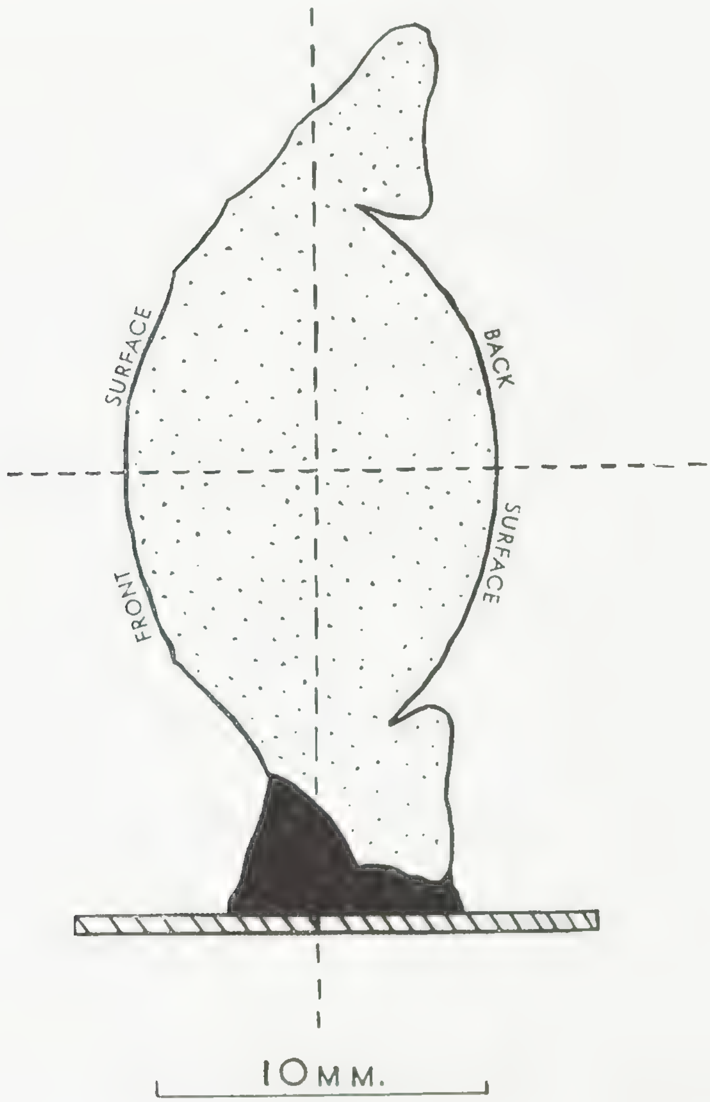


FIGURE 16.

Sketch of button-shaped australite mounted in position for deriving curvature of anterior and posterior surfaces.

Each australite was adjusted in the beam of light from a projector so that the plane containing its diameter was, as near as could be arranged by eye, parallel with the direction of the beam. Each specimen was placed in turn at the focal point of the projector lenses, and the image thrown on to a mirror set at 45°, and thence down on to the working bench. After tracing the silhouette in a convenient size (x3·75), and smoothing out minor irregularities caused by the presence of bubble pits and flow ridges, each australite was rotated to the 45° and 90° positions, when it was found, for buttons, lenses and round cores, that the silhouettes in these positions matched almost exactly the original tracing. This indicates the maintenance of a similar degree of curvature over any one particular surface, and shows that both the posterior and the anterior surfaces each form portions of different hemispherical surfaces.

For elongate australites such as ovals, boats, and canoes, two different silhouette tracings (cf. text figure 20) were obtained for two positions at right angles, corresponding to the major and minor diameters of the forms. One tracing therefore corresponds to the outline of a section taken in a plane at right angles to the major diameter and containing the minor diameter and the depth, and the other corresponds to the outline of a section taken in a plane at right angles to the minor diameter and containing the major diameter and the depth. The major diameter is hereafter referred to as the length, and the minor diameter as the width of the elongated australites.

For the dumb-bell and teardrop-shaped australites, only the silhouette outlines of end-on aspects were traced, i.e. corresponding to the outline of a section taken in a plane at right angles to the length and containing the maximum width and maximum depth of the bulbous portions of these forms.

For each arc of curvature obtained in this way for both the anterior and posterior surfaces of 215 australites from the Nirranda Strewnfield, three chords were constructed, bisected, and normals drawn through the mid-points. Most of these provided three point intersections, some showed a small triangle of error. With the intersections as foci, constructed circles were superposed upon each arc of curvature obtained from the silhouettes, and in most there was perfect concordance, in a few, minor departures occurred towards the edges—i.e. in the equatorial regions where the anterior surfaces of some flanges on flanged forms, were slightly flattened over a minor portion of the arc of curvature.

The arcs of curvature of the two surfaces of almost all of these australites, are themselves minor arcs of curvature, seldom being more than 30 per cent. of complete circles in round forms, 45 per cent. in end-on aspects of ovals, boats, canoes, dumb-bells and teardrops, and only 25 per cent. and less in side aspects of the elongate australites such as boats and canoes. The possibility therefore exists that some of the arcs of curvature among round forms of australites could correspond to certain parts of the arcs of curvature of ellipses rather than of circles (cf. text figure 21); in other words, some forms, especially the elongate forms, have evidently been derived from spheroids of revolution (text figures 31 and 32), and not all from spheres (text figure 30).

From the nature of the arcs of curvature for australites most likely to have been derived originally from spheres, it is evident that any vertical section cutting through the anterior surface, through the posterior surface and through the

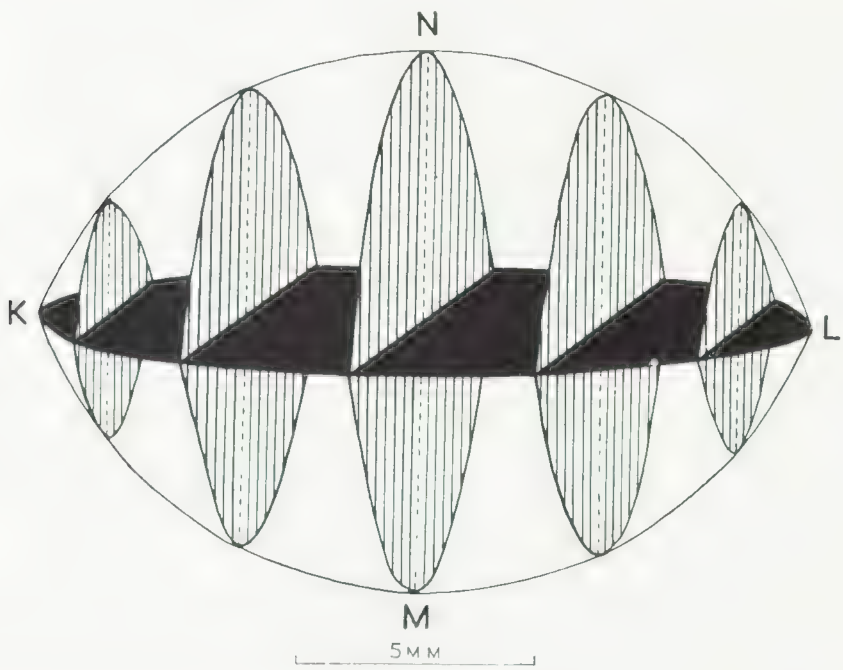


FIGURE 17.

Sketch illustrating nature of planes in a round-form of australite, where the anterior and posterior surfaces form the minor arcs of two intersecting coaxal circles.

equatorial regions of these round forms (i.e. forms that are circular in plan aspect), will show the curvatures of the anterior and posterior surfaces as the minor arcs of two intersecting, virtually coaxal circles (see text figure 17).

Only radial sections passing through the front pole (M in text figure 17) and back pole (N in text figure 17), will provide a true measure of the maximum depth and diameter values (i.e. NM and KL respectively in text figure 17). The plane KNLM in text figure 17 is one such radial section; the plane containing NM is another. All vertical sections parallel to the plane containing NM will have a generally similar shape, but will be of smaller size, and hence will not give true measures of the depth and diameter values. The horizontal plane containing the radical line KL (plane shown as solid black in text figure 17) is of circular outline, similarly all other parallel (but smaller) planes above and below this plane. The arc of curvature KNL never does, and KML seldom does, reach a stage in australites where they represent sections through the entire arc of curvature of a hemisphere. Only in rare examples of complete buttons do the anterior surfaces approach a hemisphere in size, and only in the very rare round hollow forms (cf. text figure 33B) do posterior and anterior surfaces each approach hemispherical dimensions.

Radii of Curvature Values.

The ranges of the measured values of the radii of curvature of anterior and posterior surfaces for the different shape groups among the Nirranda Strewnfield australites, are shown in Table X. The two different radii of curvature are connoted by the symbols R_F and R_B respectively. R_F represents the radius of curvature of the secondarily developed front (anterior) surface, while R_B represents the radius of curvature of the back (posterior) surface which is regarded herein as a remnant of the original primary surface.

In Table X, the values for R_F and R_B are given to the nearest 0·1 mm., and have been derived by dividing the values obtained on measurement of the enlarged silhouette diagrams by the reduction factor 3·75. The infinity sign in Table X refers to forms that possess almost flat surfaces in certain aspects, and there are only a few such forms. The T.S. heading to some columns in Table X refers to values determined from silhouettes obtained normal to the length and parallel to the depth and width measurements of elongate forms, while L.S. refers to those determined parallel to the length and depth and normal to width measurements of elongate forms. Where the ranges in R_F and R_B are set out in the L.S. columns in Table X,

the numbers of measurements possible were limited by employing fragments that gave satisfactory measurements for the T.S. values only, hence (*a*) refers to L.S. measurements obtainable

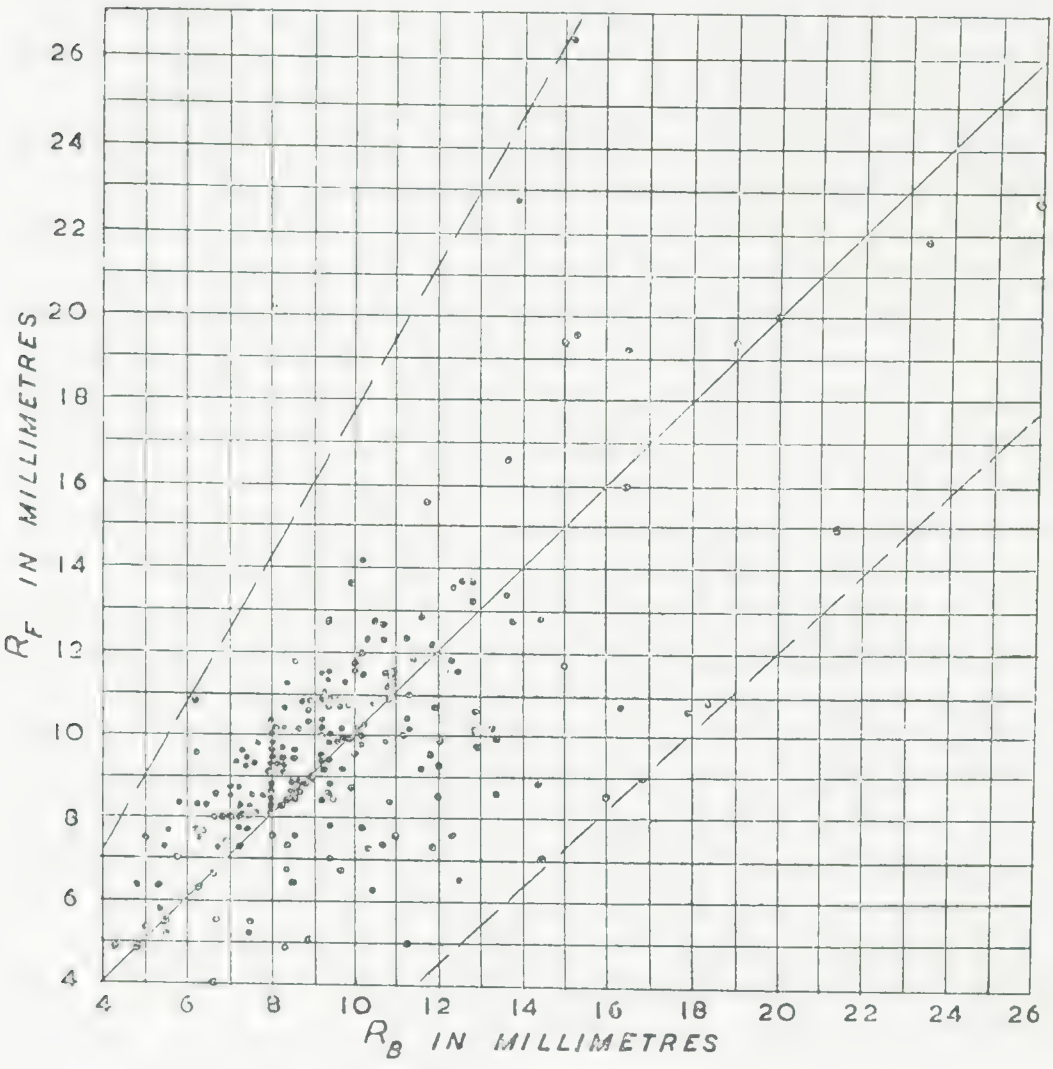


FIGURE 18.

Scatter diagram showing radius of curvature values for anterior and posterior surfaces of Nirranda Strewnfield australites.

from seven specimens only, (*b*) to four specimens, (*c*) to two specimens, (*d*) to three specimens, (*e*) to ten specimens, (*f*) to fourteen specimens, (*g*) to two specimens, and (*h*) to one specimen only.

TABLE X.

Showing percentage relationships and ranges of $R_F > R_B$; of $R_F = R_B$, and of $R_F < R_B$ for each shape group.

Group.	Total Number	$R_F > R_B$ (to 0·1 mm.). No.	%	T.S. R_F Range.	T.S. R_B Range.	L.S. R_F Range.	L.S. R_B Range.	$R_F = R_B$ (to 0·1 mm.). No.	%	T.S. R_F Range.	T.S. R_B Range.	L.S. R_F Range.	L.S. R_B Range.	$R_F < R_B$ (to 0·1 mm.). No.	%	T.S. R_F Range.	T.S. R_B Range.	L.S. R_F Range.	L.S. R_B Range.
Buttons ..	38	24	63	8·5 to 12·9	7·0 to 11·7	..	..	3	8	10·2 to 13·5	10·2 to 13·5			11	29	8·3 to 16·0	[illegible]·9 to 17·9		
Lenses (+ fragments) ..	81	49	61	7·0 to 14·1	5·8 to 13·6	..	..	9	11	8·4 to 12·0	8·4 to 12·0	.		23	28	4·0 to 11·8	6·7 to 19·2		
Ovals (+ fragments)	41	21	51	5·3 to 12·8	5·0 to 10·6	8·8(a) to 14·8	7·3(a) 14·4	4	10	6·4 to 9·2	6·4 to 9·2	10·1(c) to 13·9	10·1(c) to 13·9	16	40	5·0 to 11·0	6·7 to 80·8	7·5(e) to 13·0	8·5(e) to ∞
Boats (+ fragments)	22	18	82	6·4 to 12·9	4·8 to 10·7	15·7(b) to 41·6	11·7(b) to 20·5	1	4	9·3	9·3	∞(d)	∞(d)	3	14	7·5 to 7·8	8·0 to 9·3	10·4(f) to 18·0	13·8(f) to 37·6
Canoes	2	..	..	..	..	..	..	2	100	4·8 to 7·2	4·8 to 7·2	.		..	.			13·7(g) to 18·6	42·7(g) to ∞
Dumb-bells (+ fragments)	4	3	75	4·8 to 7·7	4·3 to 5·6	..	..	1	25	5·5	5·5		.		..				
Teardrops	2	1	50	5·8	5·4						.			1	50	5·1	5·5		
Cores (+ fragments)	20	3	15	19·4 to 26·4	15·2 to 19·0	..	..	2	10	20·0 to 30·1	20·1 to 30·1	.		15	75	6·1 to 22·7	[illegible]·4 to 26·1	25·6(h)	31·5(h)
Hollow Forms .	5	5	100	12·8 to 22·8	9·3 to 16·5							.	.						
Totals	215	124	58	4·8 to 26·4	4·3 to 19·0	8·8 to 41·6	7·3 to 20·5	22	10	4·8 to 30·1	4·8 to 30·1	10·1 to ∞	10·1 to ∞	69	32	4·0 to 22·7	5·5 to 80·8	7·5 to 18·6	8·5 to ∞

In each group, the greatest percentage of forms have RF greater than RB. Forms with RF and RB the same in value, are in the minority, those with RF less than RB are intermediary in number. This relationship is further brought out in the scatter diagram shown in text figure 18, where the RF and RB values for individual australites have been plotted to the nearest 0·25 mm.

A few higher values for RF and RB lie outside the scatter diagram shown in text figure 18. These are values for forms with (i) RF = 30 mm and RB = 30 mm., (ii) RF = 25·5 mm. and RB = 31·5 mm., (iii) RB = 81 mm., and (iv) one or two forms having almost flat primary surfaces, so that RB values are infinite and may thus be regarded as parts of the arc of curvature of spheres having infinite radius, whose centres are at infinity on the axes, or else parts of flattened spheroids of revolution.

Except in the flat-topped forms, the values for RF and RB do not vary widely from shape group to shape group. End-on aspects of dumb-bells and teardrops naturally provide the lowest radii of curvature values, while the greatest values are found in the largest of the cores and the larger of the hollow forms. Intermediary values as for buttons, lenses and ovals show no particularly significant variations. The small variations that do exist are functions of the sizes of the primary forms from which these secondary shapes were derived, as far as the RB values are concerned, and the degree of ablation suffered, as far as the RF values are concerned.

The fact that sometimes the RF value of any particular australite is greater than its RB value simply reflects the flatter arc of curvature of the anterior surface, and the development of a flatter arc of curvature for anterior surfaces is only to be expected with ablation of the original hemispherical front surfaces of the majority of the forms.

Effects of RF—RB Variations.

The effect of having (i) RF less than RB, (ii) RF equal to RB, and (iii) RF greater than RB is illustrated diagrammatically in text figure 19.

In text figure 19, diagrams A, B and C are typical of the cross sectional aspects of australites that are circular in plan, the sections being taken through the back (N) and front (M) poles of the objects. NM represents the depth of each form, KL

the diameter, and O the point of intersection of NM and KL. KNL is the arc of curvature of the back surface and KML that of the front surface in each diagram.

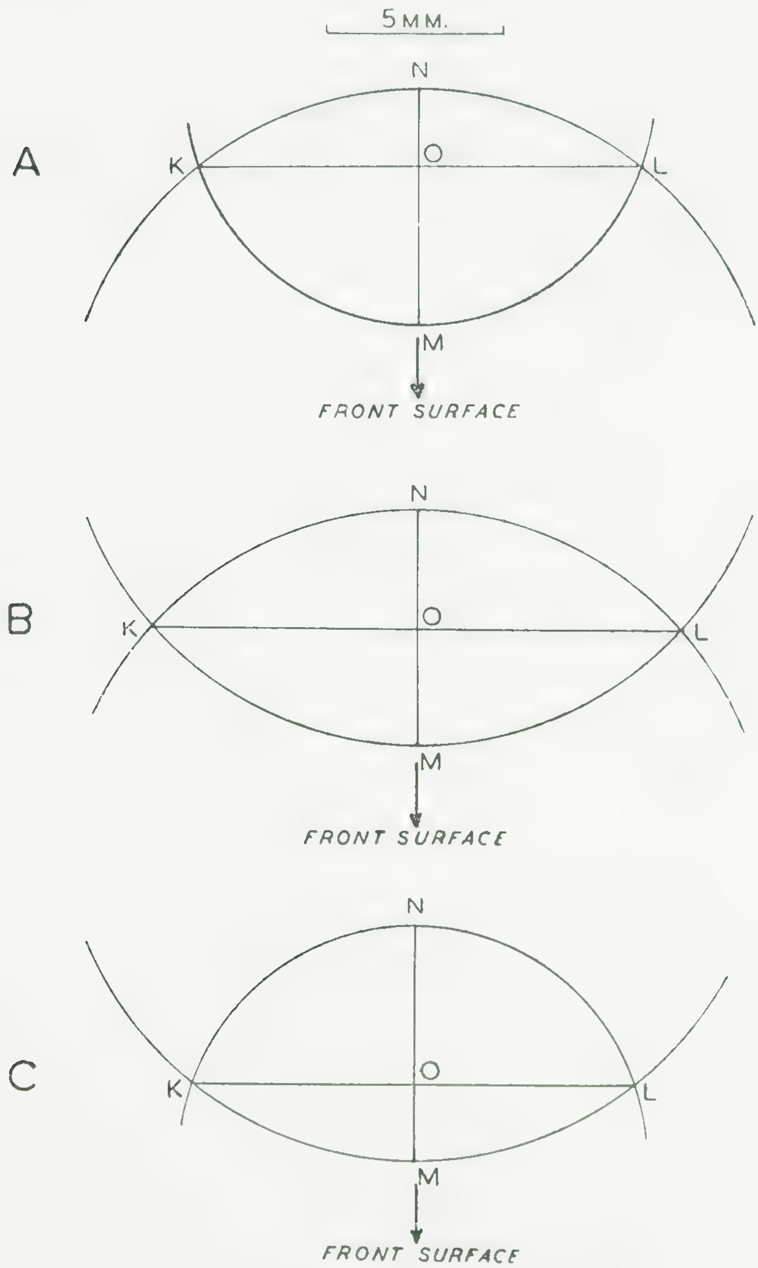


FIGURE 19.

Sections through australites showing in outline the relationships of varying curvature of posterior and anterior surfaces.

Depending upon the depths of the australites and the points of intersection of the two varying arcs of curvature for posterior and anterior surfaces respectively, the radical line (the line joining the points of intersection of the two coaxal circles of which the two arcs of curvature are part) will be nearer to or further from the front poles of australites, as indicated in text figure 19.

When RF is greater than RB, the sectional aspect is that of diagram C (text figure 19), where the front surface is somewhat flatter, O is nearer to the front pole (M), and less ablation has occurred than in either of the examples represented by diagrams A and B (text figure 19). In this example (diagram C, text figure 19) and in the one represented by diagram A (text figure 19), the horizontal plane containing KL is no longer a plane of symmetry, but NM is.

With RB greater in value than RF (text figure 19, diagram A), the arc of curvature of the rear surface is the flatter, O is nearer the back pole (N), and considerable ablation has occurred on a primary sphere that originally had a somewhat greater diameter than is represented in diagram C (text figure 19). In these and practically all other round forms of australites there has been maintenance of symmetrically curved surfaces throughout the processes of ablation producing the secondary shapes. Various stages occur between those represented by examples depicted in diagrams A and C (text figure 19); the example illustrated in diagram B represents the average relationship. The series indicates that at the outset the trend in primary spheres, on ablation, is for the radius of curvature of the front surface to increase, and hence for this surface to become flatter in its arc of curvature compared to that of the unaltering back surface. This condition holds until the average relationship (diagram B, text figure 19) is reached, but thereafter, as RF decreases with respect to RB, the arc of curvature of the front surface sometimes, but not always, becomes steeper compared with that of the back surface, evidently because of greater ablation in equatorial than in front polar regions, at the smaller sizes.

The cross sectional aspects of such types of australites are equivalent to the silhouettes utilized in determining the radii of curvature and, in them, the outlines represent the shapes produced by two intersecting circles. The line joining the points of intersection, i.e. the radical line, is a common chord to both

circles and represents the diameter of australites. In the majority of examples it has been found by construction that the line joining the centres of the two intersecting circles is perpendicular to the radical axis, hence the two centres are collinear and the circles are thus coaxal circles. It also follows that this perpendicular line where it intersects the front and rear poles of each australite provides a measure of the true depth of the form. Such relationships indicate that most australites maintained a relatively stable position throughout the period of transit through the earth's atmosphere. In very few examples the two intersecting circles are not quite coaxal, and forms represented by this relationship evidently may have contracted a slight wobble from buffeting effects during rapid forward propagation.

The depth values (NM) of these australites vary according to (*a*) the values for R_F and R_B in each particular form, and (*b*) the proximity of the centres of the intersecting circles to O in text figure 19. This, again, is ultimately a function of the degree of ablation to which any particular original sphere of australite glass was subjected.

When R_F and R_B are equal, the two arcs of curvature are the same and O is equidistant from the back and front poles (see diagram B, text figure 19). The outline of the form in sectional aspect is then that of a biconvex lens having one plane (horizontal plane) of symmetry along KL, and radial symmetry through NM for the round (in plan aspect) forms of australites.

When two (or more) comparable forms have the same R_B and the same diameter they most often have different depth values. Hence their R_F values differ, and the arc of curvature of one front surface is either flatter or steeper than in the other form (or forms), indicating variations in degree of ablation of two originally similar primary spheres of australite glass.

Conversely, when two (or more) forms have the same R_F values and the same diameter, but different R_B and depth values, the arc of curvature of one back surface is flatter than that of the other, indicating two originally dissimilar sizes of australite glass spheres. In order to produce similar arcs of curvature of the two front surfaces from two original spheres of different diameter, one sphere must have been subjected to greater degrees of ablation than the other, and this can have come about as a consequence of slight differences in the time of transit through

the earth's atmosphere, arising from different angles of traverse, so that one, in effect, travelled through a greater thickness of atmosphere than the other.

Fenner's (1934, p. 66) statement that no two australites are alike in the Shaw Collection is also applicable to most known Victorian australites. There are in the Nirranda Strewnfield australite collection, however, three lens-shaped forms (reg. nos. E865, E866 and E867) that are almost identical in surface features, they have the same depth and diameter values, the R_F and R_B values are approximately equal with a maximum variation from lens to lens of only 0·5 mm. Differences of weight are up to only 0·3 grams, and in specific gravity of up to 0·05. Although therefore not identical in every respect, these three lenses are generally very much alike in practically all of their characteristics. The conclusion to be drawn from these observations is that several similar size spheres of australite glass were formed primarily, irrespective of slight variations in specific gravity, and were subjected to similar amounts of ablation during their supersonic flight through the earth's atmosphere, producing similar secondary shapes with similar arcs of curvature of their forwardly-directed surfaces.

Oval-shaped australites have a longer and a shorter diameter (Plate IV, figure 23), with one of these diameters a few millimetres longer or shorter than the other. In two positions at right angles there are thus two different arcs of curvature for each of the posterior and anterior surfaces, and there are two radical lines of different length, as indicated in text figure 20.

K′L′ is the radical line (representing the diameter) across the shorter axis of the oval-shaped form sketched in text figure 20, and KL the radical line representing the longer diameter for the position at right angles. The radius of curvature of the front surface is greater for the longer than for the shorter diameter, hence its arc of curvature is somewhat flatter. The same applies to the back surface. Two pairs of coaxal circles result, with the members of separate pairs in contact at the front and rear poles respectively, and intersecting each other at K and L for the long diameter, and at K′ and L′ for the shorter diameter. The sketch in text figure 20 is of a form where R_F and R_B are of much the same value. There are other examples where R_F is greater or less than R_B but, in them, the general relationships of the curvatures of the two surfaces in the two positions at right angles are as depicted in text figure 20.

From such relationships as these it is deduced that oval-shaped australites were derived from spheroids of revolution rather than from spheres, despite the fact that each arc of curvature accords with the arcs of curvature of constructed circles. The reason for this accordance is again to be ascribed to the fact that the curved surfaces of these australites correspond with only minor arcs of such circles, just as do certain portions of the arcs of curvature of spheroids.

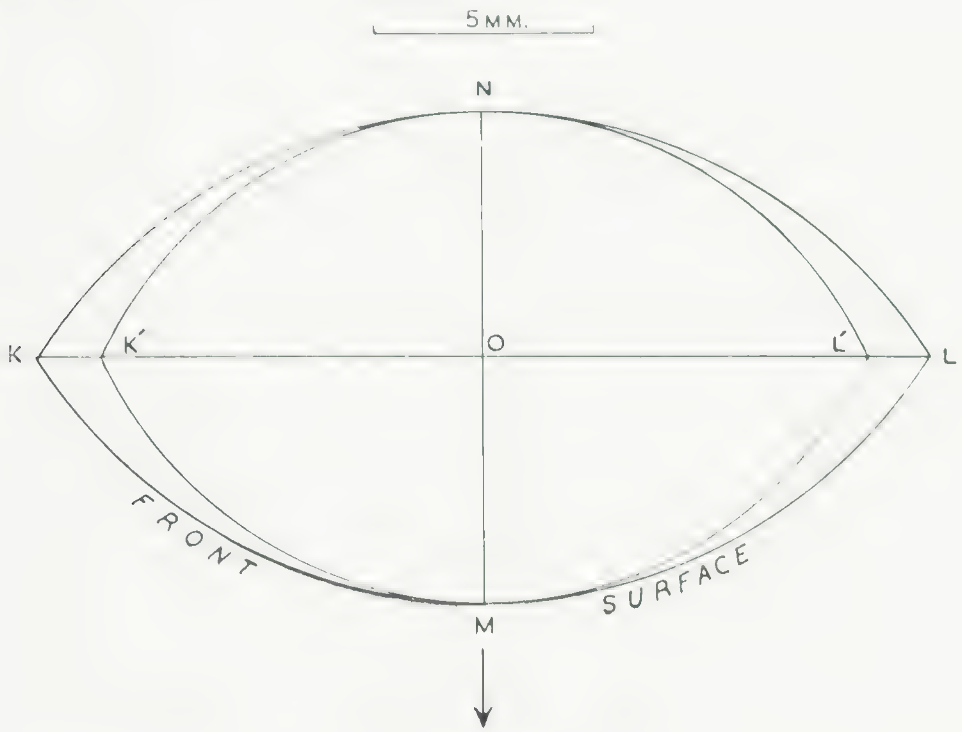


FIGURE 20.

Diagrammatical representation of two sections in right-angle positions through an oval-shaped australite, showing variations in arcs of curvature, meeting at N and M respectively for a constant depth, and different lengths of the radical lines KL and K′L′.

Much the same relationships exist for boat- and canoe-shaped australites as for oval-shaped forms, except that differences in length between KL and K′L′ (see text figure 20) are considerably increased, hence there are greater differences in the radii of curvature for each diameter of the front and back surfaces respectively, so that much flatter curvatures result along the direction of the longer diameter. It is thus even more likely that boats and canoes were derived from spheroids of revolution rather than from spheres, such spheroids being originally more

elongated along one axis than were the primary spheroids from which oval-shaped australites were derived. Some of the possible cross sectional aspects of these elongated specimens of australites are shown in a cross section through a spheroid of revolution in text figure 21.

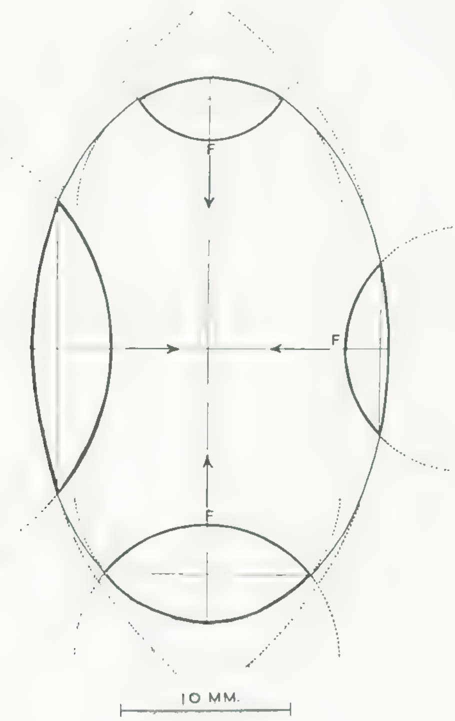


FIGURE 21.

Cross sections of elongate australites depicted as being derived from four positions of a spheroid of revolution.

For convenience in text figure 21, four possible cross sections are shown in the cross section through one spheroid of revolution. F indicates the forward surface for each form developed after ablation of the spheroid. Slightly varying cross sections would result for the end products by commencing with a spheroid of revolution of different length—breadth relationships to those shown in text figure 21. Considered as a prolate spheroid traversing the earth's atmosphere at supersonic speeds, and with its longer axis parallel with the direction of propagation, the top and bottom cross sectional aspects of the final shapes produced (text figure 21) could well be those of some lens- and button-shaped australites, as well as of oval-shaped forms having minor differences between the longer and shorter diameters, because

the arcs of curvature in these positions conform also to the arcs of curvature of small spheres (indicated by the broken lines of part circles at the top and bottom of text figure 21), as well as to the arcs of curvature around the top and bottom poles of the spheroid of revolution.

Considered as an oblate spheroid, the two sections depicted on the left- and right-hand sides of the sketch (text figure 21) conform to the longitudinal sections through boat- and canoe-shaped australites, i.e. forms which usually have a much flatter curvature of the posterior than of the anterior surface, and which are longer than broad. Here again, the arc of curvature of the posterior surface for each example can conform to part, although a very minor part, of the arc of curvature of a constructed circle (indicated by the broken lines of part circles on the left- and right-hand sides of text figure 21) with a greatly increased radius compared with that constructed around the front and back poles of the spheroid itself.

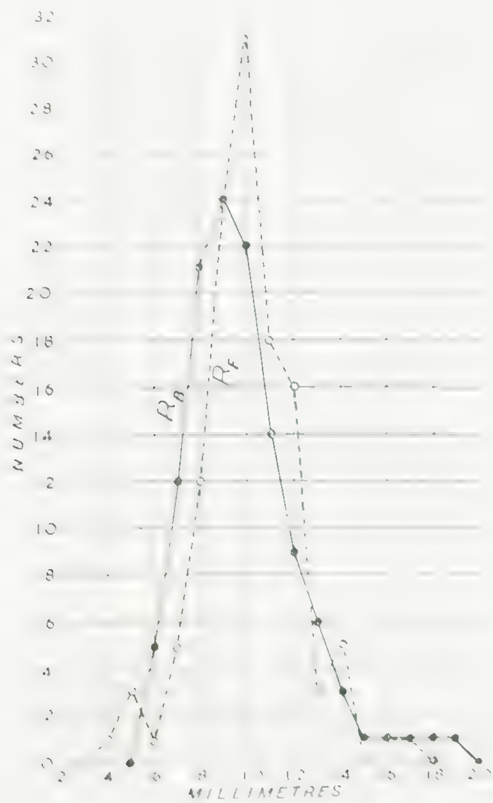


FIGURE 22.

Frequency polygons for RF and RB of the Nirranda Strewnfield australites.

The relationships between numbers measured and the values resulting from measurements of R_F and R_B in button- and lens-shaped australites from the Nirranda Strewnfield are shown in text figure 22.

The frequency polygons shown in text figure 22 verify the observation that R_F is generally greater than R_B among the Nirranda Strewnfield australites, the mode for R_F occurring on the 10 mm. co-ordinate, while that for R_B lies on the 9 mm. co-ordinate. It also transpires that these modal values tally with a relatively common combination among button- and lens-shaped australites, i.e. many forms have R_F values of 10 mm., and R_B values of 9 mm.

Relationships of R_F and R_B to Depth and Diameter Values.

The scatter diagrams shown in text figures 23 to 26 indicate distribution relationships as between (i) R_F and diameter, (ii) R_F and depth, (iii) R_B and diameter, and (iv) R_B and depth. They also provide a record of these values for each individual australite collected from the Nirranda Strewnfield for which such measurements could be obtained.

Text figure 23 shows that most of the Nirranda Strewnfield australites possess diameter values that are a little greater in amount than the R_F values. The same applies for R_B–diameter relationships shown in text figure 25. The position is reversed for R_F–depth (text figure 24) and R_B–depth (text figure 26) relationships, where a greater number of forms have both the R_F and the R_B values greater in amount than the depth values, although there is a somewhat larger number of individuals with depth values greater than R_F and R_B values than there are with R_F and R_B values greater than diameter values. Moreover, there are rather more individuals with depth values greater than R_B values than there are with depth values greater than R_F values. These relationships are expressed on a percentage basis in Table XI.

Relationships of the Intercepts Made by the Radical Line Upon the Depth Line of the Nirranda Strewnfield Australites.

The intercepts of the radical line upon the depth line of the Nirranda Strewnfield australites are indicated diagrammatically in text figures 19 and 20, where the length cut off between the front pole and the point of intersection of the radical

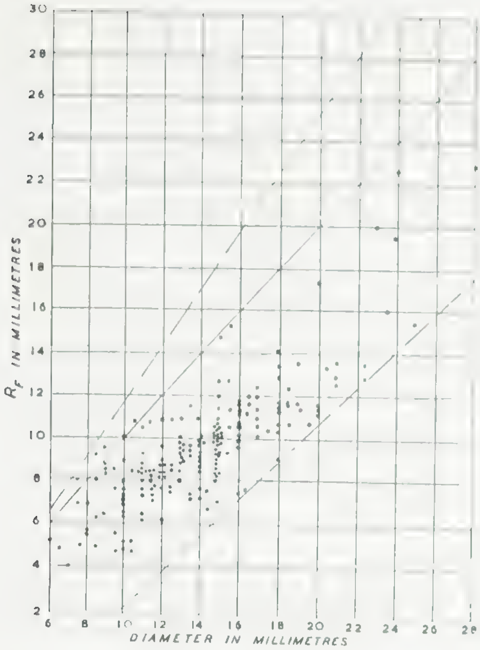


FIGURE 23.

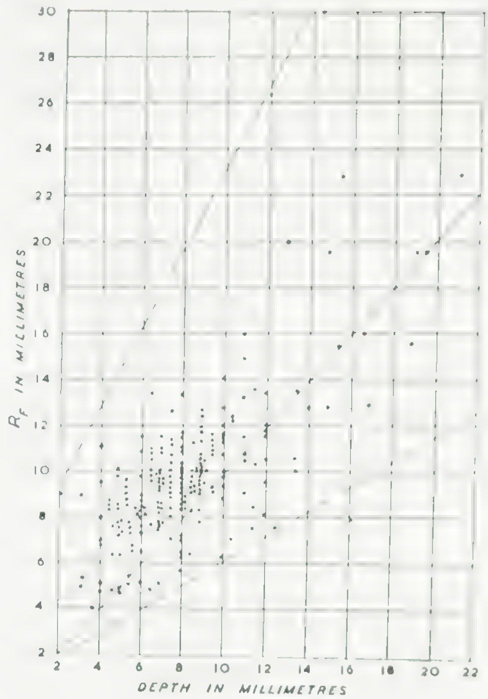


FIGURE 24.

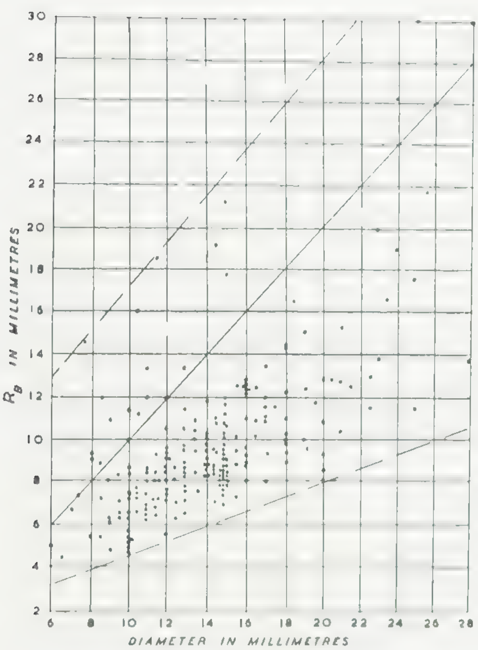


FIGURE 25.

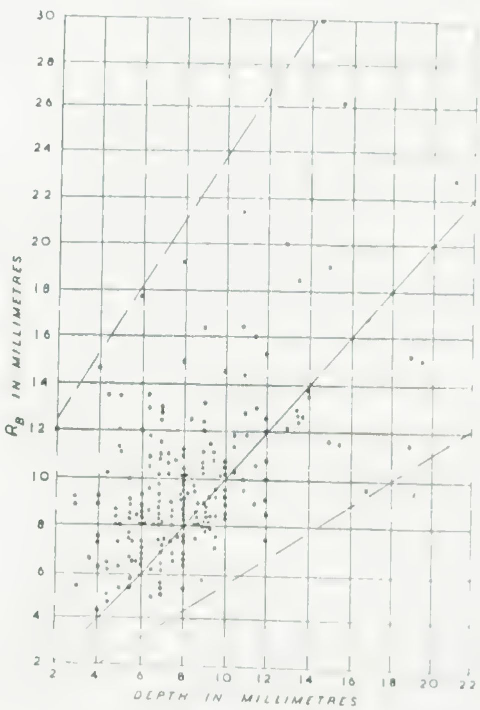


FIGURE 26.

Scatter diagrams showing relationships of radius of curvature of anterior (R_F) and posterior (R_B) surfaces to diameters and depths of australites from the Nirranda Strewnfield.

line with the depth line is represented by the length OM, and that for the back pole by ON. OM and ON values therefore represent the distances of the front and rear poles respectively from the centre of the radical line for each of the australites from which the relevant information could be obtained.

The relationships of the measured values for OM and ON are presented in text figure 27, where the values have been plotted to the nearest 0·25 mm.

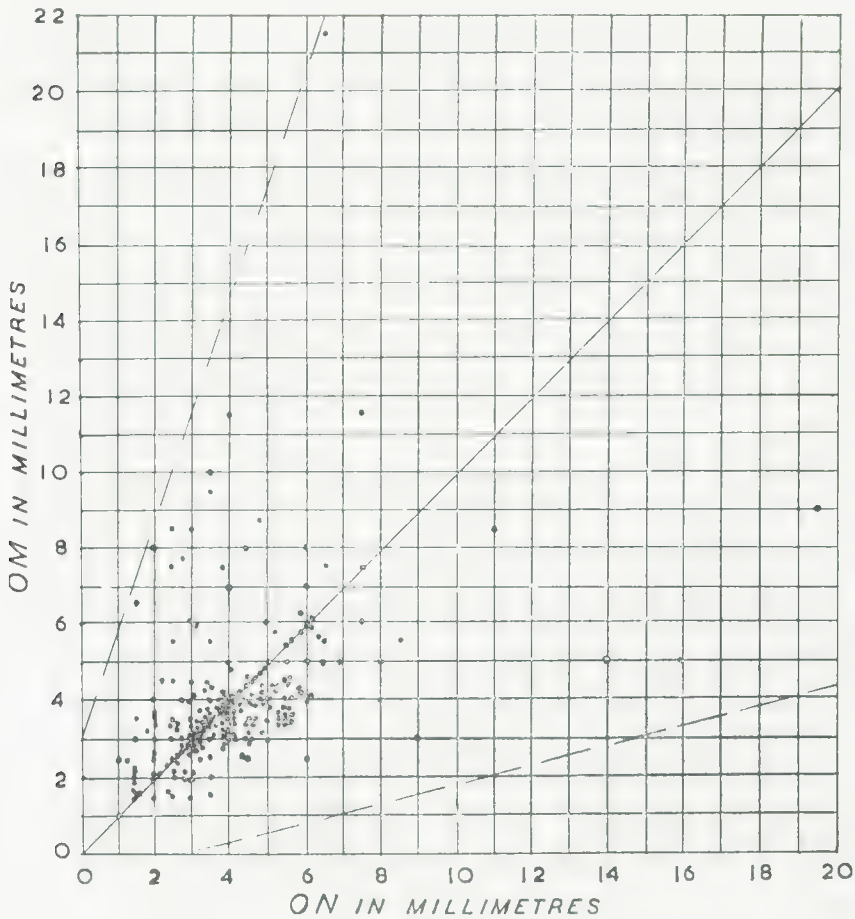


FIGURE 27.

Scatter diagram showing OM ON relationships for Nirranda Strewnfield australites.

A large number of the values are clustered along the lower limits of the unit gradient line, indicating that in many of the australites the front and back poles are more or less equidistant from the radical line and, in many, these values are low and

show differences of little more than 1 mm. A small number of forms possess ON values that are greater than OM values, and vice versa, in terms of the scatter diagram (text figure 27). In them, therefore, a few of the australites have a greater bulk of glass on the back polar side of the radical line, and a few have the greater bulk on the front polar side. This state of affairs in no way upset the stable position of flight of australites through the earth's atmosphere. The greater number of forms, in which OM and ON are equal or almost so, possess similar amounts of glass on either side of the radical line. This is only a generalization, however, as can be gathered from inspection of Table XI, where the percentage calculations are based on values taken to the nearest 0·1 mm.

The relationships of OM and ON throughout are fundamentally controlled by the radius of curvature of the front surface compared with that of the back surface. In addition, since the arcs of curvature of these two surfaces represent minor arcs of coaxal circles, they are also controlled by the positions of intersection of the two surfaces in the equatorial regions of the australites; in other words, the distance apart of the centres of the coaxal circles.

Extreme examples where OM : ON :: 3 : 1, and where ON : OM :: 3 : 1 are very rare. Since the intercepts OM and ON are intimately related to the radii of curvature R_F and R_B, the ratios of OM to ON and of R_B to R_F have been calculated and are plotted side by side in the frequency polygons represented in text figure 28.

The inset diagram in text figure 28 provides a key to the measured values from which the ratios have been determined. The ratios have been plotted from calculations based on determinations taken to the nearest 0·25 mm., and both the frequency polygons reveal prominent modes at unit ratio. In the calculation of the ratios OM : ON, OM was retained at unity throughout. The greatest numbers (85 per cent.) with ratios of OM and ON approximating unity, contain most of the button- and lens-shaped forms that are more or less regularly lenticular in side aspect, and which thus have the radical line spaced approximately equidistant from the front and back poles respectively. To the left of the mode of the left-hand frequency polygon in text figure 28 occurs the group of the cores, wherein OM is mainly greater than ON. To the right of this same mode occurs a lesser

number of button-, lens- and oval-shaped forms where OM is mainly less than ON, and such forms have slightly flatter posterior than anterior surfaces.

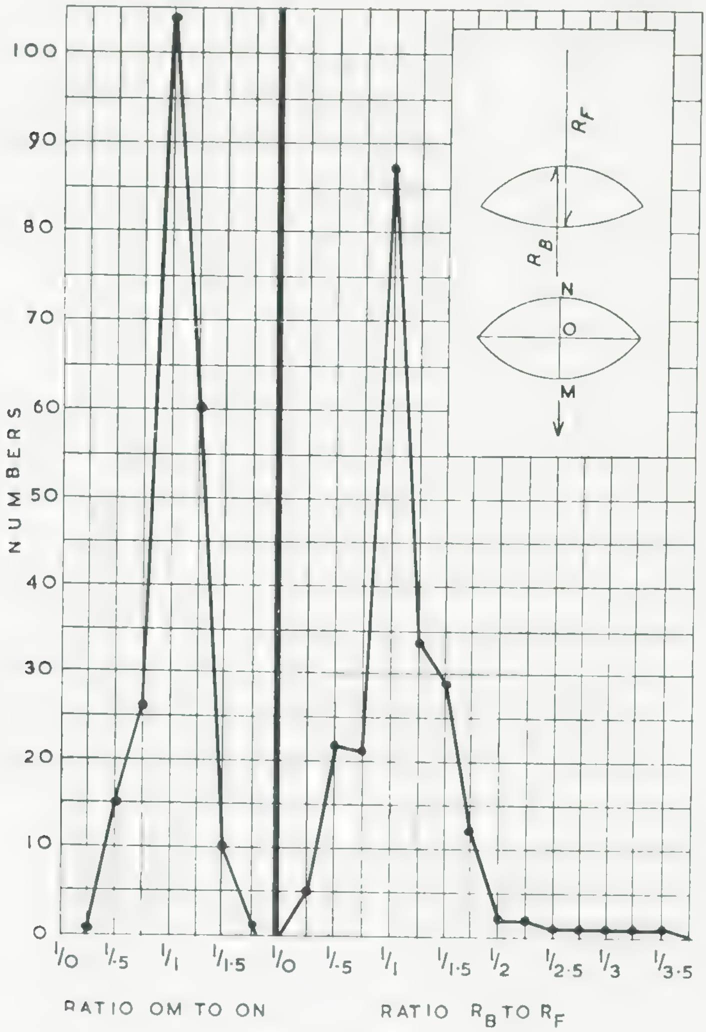


FIGURE 28.

Frequency polygons showing distribution of ratios of OM to ON, and of R_B to R_F for Nirranda Strewnfield australites.

In the frequency polygon showing the relationships of numbers to the $R_B : R_F$ ratio (right-hand diagram in text figure 28), a range in ratios of 1/0·25 to 1/3·5 is shown. R_B has been retained at unity. The greater number of examples occur on and within the immediate region of the 1·0/1·0 ratio,

TABLE XI.

Factors Compared.	Relationship of Factors.	Percentage.
R_F—R_B	$R_F > R_B$	60·0
	$R_F = R_B$	8·5
	$R_F < R_B$	31·5
Di—De	Di > De	100·0
	Di = De	0
	Di < De	0
R_F—Di	$R_F >$ Di	2·5
	$R_F =$ Di	2·5
	$R_F <$ Di	95·0
R_B—Di	$R_B >$ Di	9·5
	$R_B =$ Di	1·5
	$R_B <$ Di	89·0
R_F—De	$R_F >$ De	80·0
	$R_F =$ De	5·0
	$R_F <$ De	15·0
R_B—De	$R_B >$ De	66·5
	$R_B =$ De	5·0
	$R_B <$ De	28·5
OM—ON	OM > ON	25·0
	OM = ON	28·0
	OM < ON	47·0
R_F—OM	$R_F >$ OM	97·7
	$R_F =$ OM	0·9
	$R_F <$ OM	1·4
R_F—ON	$R_F >$ ON	100·0
	$R_F =$ ON	0
	$R_F <$ ON	0
R_B—OM	$R_B >$ OM	100·0
	$R_B =$ OM	0
	$R_B <$ OM	0
R_B—ON	$R_B >$ ON	98·1
	$R_B =$ ON	0
	$R_B <$ ON	1·9

indicating equal or approximately equal Rf and Rb values. To the right of the mode are examples with flatter arcs of curvature of the anterior surfaces, since Rf is greater than Rb. The reverse applies for examples to the left of the mode.

The several related factors (*a*) radius of curvature of anterior surfaces (Rf), (*b*) radius of curvature of posterior surfaces (Rb), (*c*) diameter (Di), (*d*) depth (De), and (*e*) the intercepts OM and ON, as determined from the measurement of just over 200 Nirranda Strewnfield australites, have been placed on a percentage basis, given in summarized form in Table XI.

From Table XI it is seen that values for Rf and Rb are mainly less than values for diameters, but greater than values for depths among the secondary shapes that constitute the australite population of the Nirranda Strewnfield, while diameters are all greater than depths. The radius of curvature of anterior surface (Rf) is greater than that of posterior surface (Rb) in almost two-thirds of the specimens.

The percentage of australites in which the members of any given pairs from among the factors Rf, Rb, Di and De are equal to one another is low throughout, being least (0 per cent.) in diameter–depth relationships and greatest (8·5 per cent.) in Rf–Rb relationships.

The lengths of the intercepts OM and ON, which represent distances from the centres of radical lines to the front (M) and back (N) poles of the australites, show from Table XI, that, in approximately one-quarter of the specimens, lengths (OM) are greater than lengths (ON). In approximately one-quarter of the specimens these two distances are equal in value, and in approximately one-half, the distances from centres to front poles are less than the distances (ON) to back poles.

Being intercepts on the depth line (cf. text figures 19 and 20), the lengths OM and ON must always be less than De, and consequently always less than Di, since Di is always greater than De. Rf is universally greater than ON and Rb greater than OM, but Rb is not always greater than ON, and Rf is not always greater than OM. There are, for example, 1·9 per cent. of the Nirranda Strewnfield australites with Rb values less than ON values, and such examples are typically the hollow forms of australites. There are also 0·9 per cent. of specimens with Rf equal to OM, and 1·4 per cent. with Rf less than OM, and these specimens are all the larger core types of australites.

Origin of the Shapes of Australites

The known shapes of australites are secondary shapes that can be traced to a few typical primary forms such as spheres and the forms of revolution consisting of prolate spheroids, oblate spheroids, apioids and dumb-bells as illustrated in text figure 29.

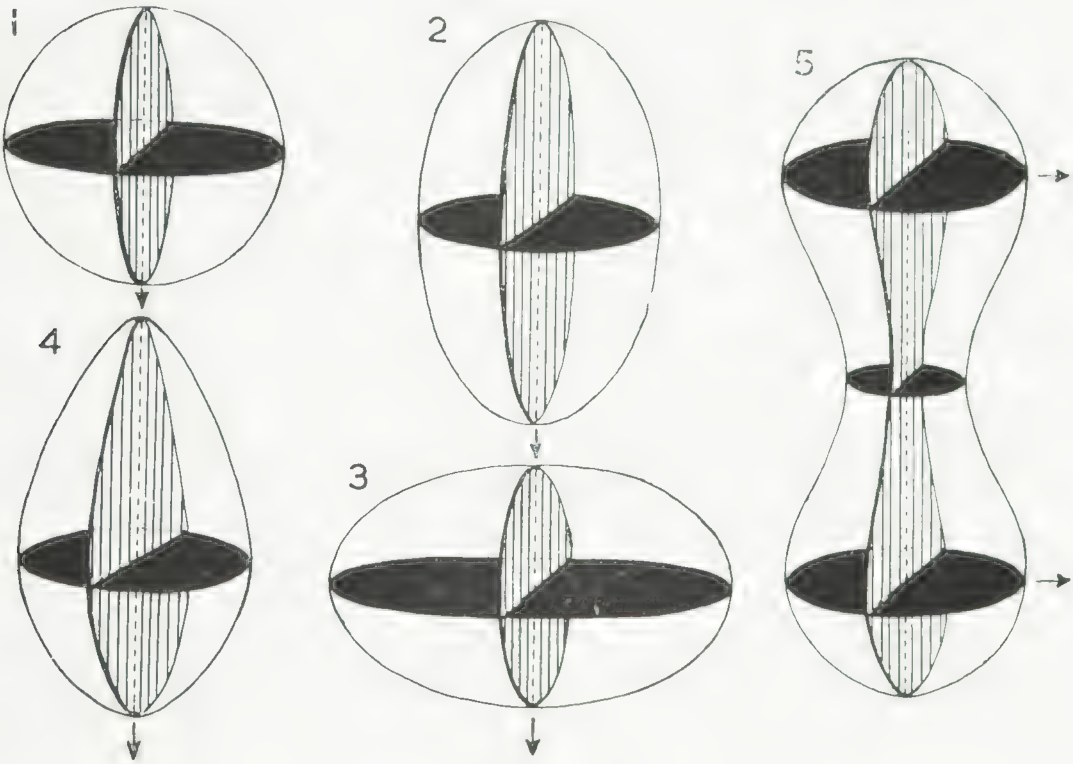


FIGURE 29.

Three dimensional sketch diagrams illustrating the sphere and the characteristic figures of revolution that constituted the primary forms from which were produced the majority of the secondary shapes possessed by australites. 1 = sphere, 2 = prolate spheroid, 3 = oblate spheroid, 4 = apioid, and 5 = dumb-bell.

In text figure 29, the arrows indicate the direction of subsequent propagation through the earth's atmosphere, and are placed at the front poles of each form. There is no evidence that forms of revolution such as the annular torus and the paraboloid were developed as primary forms of australites. The sphere is possible only when there is no rotation (cf. Kerr Grant, 1909, p. 447), the prolate spheroid is stable only at high speeds of rotation, while the oblate spheroid is stable only at low speeds

of rotation. The prolate and oblate spheroids depicted in text figure 29 are biaxial ellipsoids in the sense that they have a longer or shorter vertical axis and equal lateral axes. Triaxial ellipsoids, with the lateral axes unequal, were evidently the primary forms from which the oval-shaped secondary forms of australites were developed. They would have to be produced by a uni-directional equatorial flattening of original prolate and oblate biaxial ellipsoids, possibly near the end stages of cooling of the original rotating spheroids. Some, perhaps all, of the boat-shaped secondary shapes of australites were possibly generated from primary triaxial ellipsoids that were rather more flattened than the parent forms from which the oval-shaped secondary forms were produced.

Approximate ranges in the original sizes of the primary forms, as deduced from australites figured in tektite literature and/or examined by the writer, are set out in Table XII.

TABLE XII.

Primary Forms.	Size Range in Millimetres.
Spheres	10 to 55
Prolate spheroids	10 x 20 to 40 x 100
Oblate spheroids	10 x 20 to 40 x 100
Apioids	10 x 35 to 35 x 50
Dumb-bells	9 x 20 to 40 x 100

Among the spheres, the rare hollow examples sometimes range in size up to 60 or 65 mm. across. Among the prolate and oblate spheroids, some forms are more equal in their axial values, so that instead of being originally 10 x 20 mm. in size, some of the primary ellipsoids were more like 13 x 17 mm. in size. Other prolate and oblate spheroids were rather more massive than this, in having dimensions such as 40 x 100 mm., but some were more slender and measured in the vicinity of 10 x 50 mm. There were various gradations in the size and shape of the spheroids between the probable extremes listed above.

In the past, it has been considered (Fenner, 1934, p. 65) that the elongate forms of australites were derived from round forms by rotation in the earth's atmosphere, and that certain specimens,

such as the canoe-shaped forms, were somewhat puzzling as far as their origin is concerned. Their origin becomes more readily pictured if the primary forms are regarded as spheres and as forms of revolution developed in an extra-terrestrial environment, and if the secondary forms represented by all examples of all secondary shapes that are possessed by australites are regarded as the end results of processes of ablation affecting the primary shapes of virtually cold bodies (except for a transient, thin, partially fused front skin) travelling through the earth's atmosphere without a spinning trajectory, but at ultra-supersonic speeds.

As found upon the earth's surface, the known secondary shapes of australites are essentially modified versions of the few accepted primary forms such as spheres and primary forms of revolution. It is most likely that these forms were generated in an extra-terrestrial rather than a terrestrial environment, some instantaneously as spheres which rapidly cooled as such, others as rotating masses of molten glass that rapidly cooled to form spheroids, apioids and dumb-bells. Such bodies were evidently cold on first entering the earth's atmosphere, and the question of the origin of the secondary shapes that are possessed by australites, developed as an outcome of frontal softening in thin films followed by ablation, hinges on three possibilities, namely (i) whether they rotated through the earth's atmosphere for the whole of their earthward journey, (ii) whether some forms were spinning on first entry into the atmosphere and ceased to spin thereafter, or (iii) whether they maintained a relatively stable position of non-rotatory flight throughout the entire phase of transit through the earth's atmosphere, with only slight wobbling developed in some specimens.

Since spheres are only possible when no rotation occurs, it is not likely that they started to spin on entering the earth's atmosphere. If still spinning on entry into the atmosphere, the primary forms of revolution soon ceased to do so. Much of the evidence provided by the secondary shapes and secondary structures of australites is interpreted herein as going a long way towards indicating non-rotation while being propagated at high speeds over a short period of time through the earth's atmosphere.

Allowing for tertiary modifications brought about by ordinary processes of erosion, the secondary shapes of australites as found upon the surface of the earth, are thought

to be of a kind that can be formed from glassy bodies of pre-determined shape, travelling at ultra-supersonic velocities through a not very highly resisting medium—the earth's atmosphere—without rotating, but subject to pressure and frictional heating, surface sheet melting in thin films, fusion stripping and ablation of their forward surfaces under the influence of the effects of aerodynamical flow.

The nature of the secondary structures such as flow ridges, and the flow lines that occur with them in typical associations indicating non-rotational flight, has already been described (see text figures 13 and 14), likewise the fact that flange building can be accounted for without invoking rotation through the atmosphere. There now remains to be considered the secondary shapes themselves in relation to their primary forms, and these are dealt with in descriptions of text figures 30 to 34.

First it should be noted that the axes of the secondary shapes that constitute australites, are not always axes of symmetry like the axes of rotational symmetry possessed by the primary forms from which they were produced. Developed as secondary shapes from spheres, the buttons and lenses have equal lateral axes and always a shorter vertical axis. The vertical axis is virtually an axis of rotational symmetry, but the lateral axes are not always axes of twofold symmetry, only being so when the forms are regularly biconvex with bilateral symmetry. Oval-shaped australites have unequal lateral axes and a shorter vertical axis. Boat-shaped forms have a somewhat longer and a shorter lateral axis, and a short vertical axis that is sometimes equal to, more often less than, the shorter lateral axis. In these elongated australites, the vertical axis is no longer an axis of rotational symmetry, but is twofold.

Dumb-bell-shaped australites have one longer and one shorter lateral axis, and a short vertical axis equal to or less than the shorter lateral axis (i.e. omitting the waist region from consideration here). Among the teardrop-shaped australites, it is evident that some traversed the atmosphere in much the same way as aerial bombs, with their longer axis parallel to the direction of propagation (cf. Baker, 1946, Plate X), hence such examples have more or less equal lateral axes (considered as passing through the swollen portions of their apioid shape), and a longer vertical axis. Some teardrops, however, provide evidence of having travelled through the atmosphere in a position that might appear at first to be somewhat unstable—with the longest axis

horizontal (cf. text figure 34c, and cf. Baker, 1946, Plate IX, figures 9 and 10). The nature of the anterior surface and of the flaked equatorial zone in such forms, point to this position of flight as being a stable position, otherwise these secondary features would not have been developed in the positions that they occupy. Hence such forms are comparable with (half) dumb-bells in having a longer lateral axis, a shorter lateral axis, and a vertical axis that is shorter than the short lateral axis.

The many button- and lens-shaped australites represented among the Nirranda Strewnfield collection evidently had their origin in the ablation of primary spheres (or spheroids with nearly equal axes), as indicated in text figure 30.

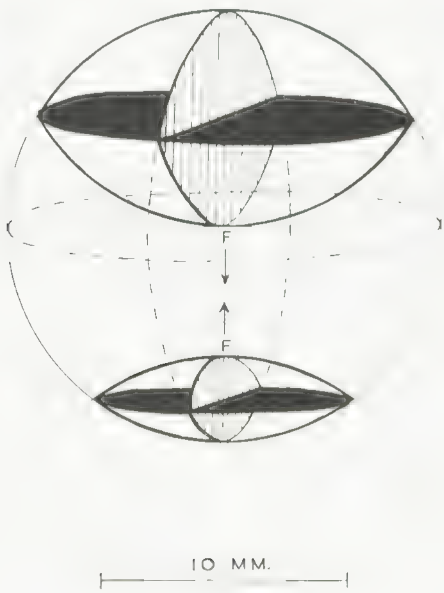


FIGURE 30.

Diagram illustrating suggested origin of button- and lens-shaped australites from a primary sphere. (Flanges possessed by button-shaped forms have been omitted).

Two secondary forms are depicted in a sketch of one sphere in text figure 30, for convenience of representation. F indicates the forwardly directed surface of each secondary form, and the arrows represent the direction of propagation through the earth's atmosphere. These arrows will naturally be directed in the same sense in actual fact. The possibility is not overlooked that similar button- and lens-shaped secondary forms could result

from the ablation of a prolate spheroid of a type indicated in text figure 31, in much the same way as from the ablation of a sphere (text figure 30). Rather more australite glass has to be ablated from the primary prolate spheroid.

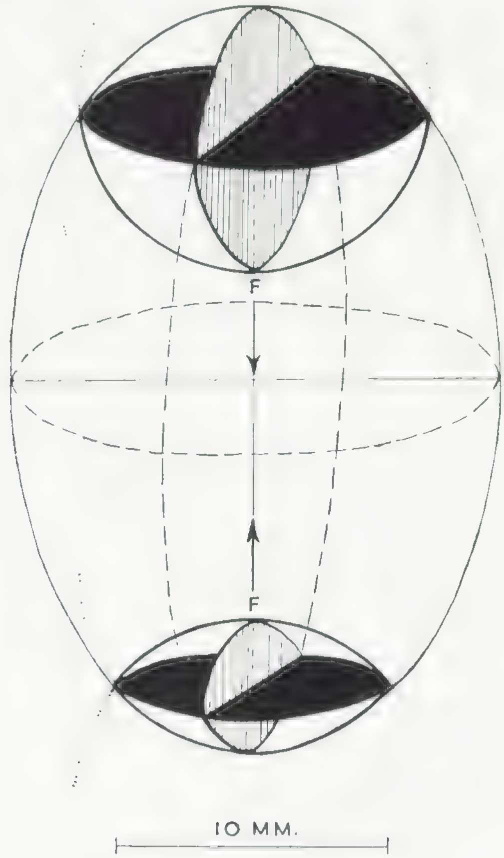


FIGURE 31.

Diagram showing secondary forms resulting from the ablation of a prolate spheroid of australite glass.

The arcs of curvature of the back (i.e. primary) surfaces of the secondary shapes of some australites conform to the arcs of constructed circles, just as do the arcs of curvature of the polar regions of certain prolate spheroids. Different arcs of curvature of the back surfaces of button- and lens-shaped australites and possibly also some oval-shaped specimens developed in this way, would arise from differently shaped (i.e. broader or narrower) prolate spheroids.

Many of the oval-shaped australites having (i) the two different radii of curvature for each of the two curved surfaces, and hence (ii) two different arcs of curvature in two positions at

right angles for each of the two surfaces, and (iii) major and minor diameters with no very marked difference in length between them, such as depicted in sectional aspect in text figure 20, probably arose from the ablation of forms of revolution less elongated than the spheroid shown in text figure 31, and yet not as spherical as the primary form shown in text figure 30. They would thus be secondary shapes intermediary between those of the button and lens groups and those of the boat and canoe groups, and had their origin in primary forms of revolution initially intermediate in shape between the primary forms of these groups.

Other oval-shaped australites, in which the two diameters are more significantly different in length, probably arose from oblate spheroids approaching the character of the example shown in text figure 32. Boat- and canoe-shaped australites certainly seem to have been derived from oblate spheroids (text figure 32).

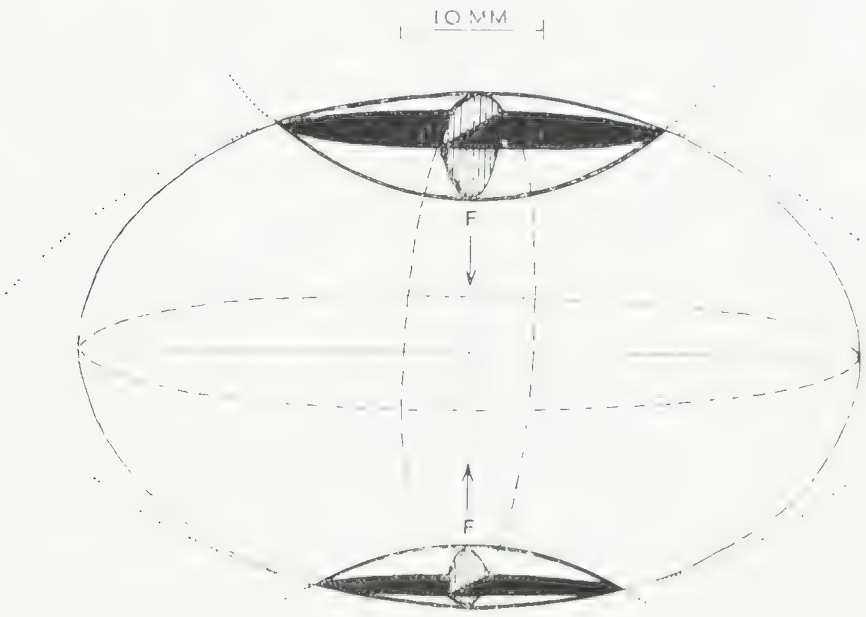


FIGURE 32.

Diagram showing elongated secondary forms such as boat- and canoe-shaped australites, developed by the ablation of an oblate spheroid of australite glass.

The australite "cores" (cf. Baker, 1940b, p. 492) or "bungs" (cf. Fenner, 1938, pp. 200, 204), are much larger than the cores (body portions) derived by the loss of flanges and peripheral regions from smaller australite forms such as buttons, lenses and ovals. These large cores have round (in plan aspect),

oval, boat and dumb-bell shapes and often, though not invariably, possess characteristic flaked equatorial zones but never flanges. They evidently represent the earliest arrested stages of larger primary forms that have been the least modified by processes of fusion stripping and ablation (cf. text figure 35).

Round cores of this nature were derived from original spheres in the manner indicated by text figure 33.

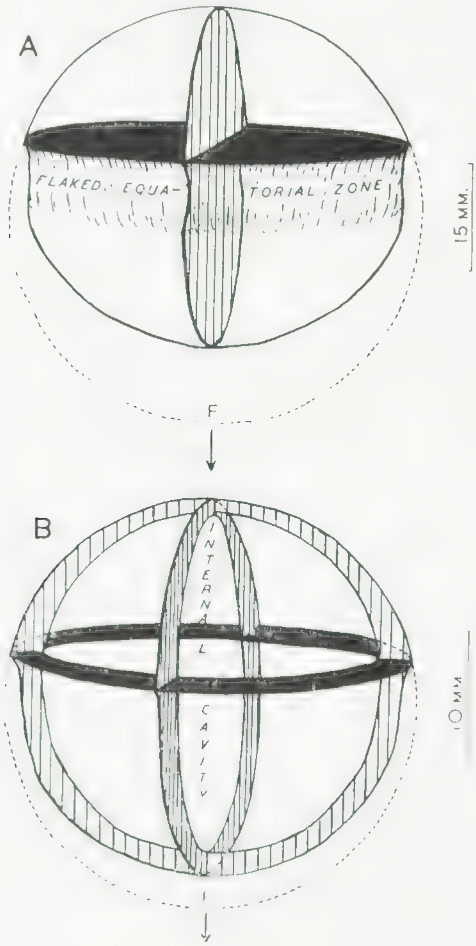


FIGURE 33.

A—round core with flaked equatorial zone, developed by fusion stripping and ablation of an original sphere (dotted line).

B—hollow form derived from original hollow sphere (dotted line represents continuation of original outer walls).

F—indicates original positions of front poles of primary spheres, and arrows indicate direction of propagation through the earth's atmosphere).

Some hollow forms of australites have the same external shape as some of the large round cores (cf. text figure 33), and have thus been subjected to similar processes of fusion stripping and ablation. Indeed, some even show similar flaked equatorial zones.

Preservation of certain hollow forms as complete entities throughout the operative phases of fusion stripping and ablation, demands the original development of a primary hollow sphere with an eccentrically disposed internal bubble, so that the walls at one pole were thicker than the walls at the opposite pole. A hollow form with an eccentrically placed bubble would be expected to travel on its line of flight with the thickest wall forward, so that the anterior surface had thicker walls than the posterior surface (cf. text figure 33B). All hollow australites, of which there are comparatively few known, provide evidence which indicates that this expected position was actually a stable position of forward propagation. Some hollow forms subjected to excessive ablation compared to the thickness of their forwardly directed walls, have collapsed inwards during flight, as evidenced by the presence of inrolled edges in certain hollow-form fragments from the Nirranda and Port Campbell Strewnfields. These inrolled edges show evidence of secondary flow of glass over the collapsed edges and inwards towards the inner walls of the original internal cavity, and the fragments on which they occur are fragments broken from the polar regions of anterior surfaces.

In text figure 33B, which is based on a sliced hollow australite from Hamilton, Victoria, figured by Dunn (1912, figure 2A, Plate 7), the thickness of the walls at the front pole was originally 10 mm., but is now 3.5 mm. on account of reduction by ablation. At the anterior pole, the glass walls were four times as thick as the walls (2·5 mm.) at the back pole. Up to approximately 8 mm. thickness of glass has thus been removed by processes of ablation from front polar regions.

A hollow australite from Horsham, Victoria, figured by Walcott (1898, Plate III, figures 1 and 1A) had an original thickness of 12·5 mm. for the walls at the front pole, while the thickness at the back pole is 2·5 mm., so that the forwardly directed walls of this australite glass bubble were originally five times as thick as the rear walls, and the internal cavity was eccentric with respect to the original walls of the primary hollow sphere.

Hollow forms with even more eccentrically disposed internal cavities, which have very much thicker anterior walls, can withstand fusion stripping and ablation to the same degree to which certain solid forms have been subjected, and yet need not collapse, by virtue of the fact that the internal cavity is situated well back towards the posterior surface. Of such a nature is an example (reg. no. E1052) from the Nirranda Strewnfield, where ablation has been operative to such an extent that a flange has been developed on a form (Plate II, figures 9 and 10) with a relatively large internal cavity. Although this form is practically complete, possessing only a small hole 1 mm. across leading to the internal cavity, it has been possible to form an estimate of the dimension of the internal bubble along the polar axis by inserting a needle through the aperture and across the internal cavity. The following dimensions were obtained:—

(1) Distance from front pole to bottom of aperture 2 mm.

(2) Distance from front pole to back wall of internal cavity .. .. .. 16 mm.

(3) Distance from front pole to back pole .. 19 mm.

By substracting measurement (1) from measurement (2), the depth of the internal cavity is arrived at as 14 mm. Measurement (1) provides the thickness of the walls at the front pole, while the difference between measurement (3) and measurement (2) shows that the thickness of the walls of the internal cavity at the posterior surface is only 3 mm. The cavity is thus eccentrically placed with respect to the positions of the front and back poles, a condition that was even more pronounced before ablation of the front polar regions. Radiographs of this form reveal the following dimensions of the internal cavity:—front polar aspect: 12 x 13 mm., two side aspects at right angles: 14 x 13 and 14 x 12 mm. respectively. The internal cavity thus has slight polar elongation.

The large elongate cores of boat-, dumb-bell and teardrop-shaped australites are indicated in text figure 34, where the primary forms from which they were derived are shown as broken lines. End-on aspects of these forms generally resemble the shape of the round core depicted in text figure 33A.

Some larger cores have flatter posterior surfaces than indicated in text figure 34, and were evidently derived from primary forms having flatter arcs of curvature along their sides.

thus approaching cigar-shaped ellipsoids they did not traverse the atmosphere end-on, however, except in rare examples of the apioids that now have aerial bomb-like shapes.

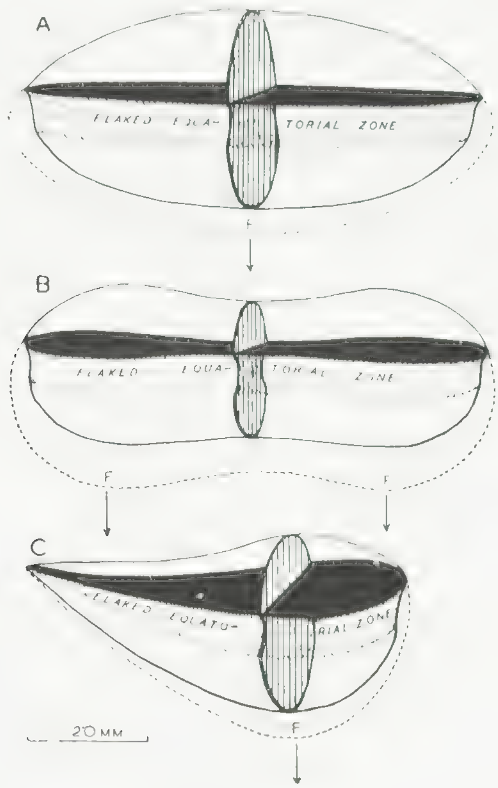


FIGURE 34.

A—elongate core (boat-shaped).

B—elongate core (dumb-bell-shaped).

C—elongate core (teardrop-shaped).

The material between the dotted lines and the anterior surfaces in each sketch, has been removed by ablation.

F—indicates position of front poles.

The elongate core shown in text figure 34A was derived, by ablation, from an oblate spheroid of revolution. For allied examples, the length of the original spheroid compared to its breadth, increases from short ovals through longer ovals to the more elongated boat-shaped cores. The flaked equatorial zone of such examples is a common feature, but one or two specimens are known in which flaked equatorial zones have not been developed. In them, the anterior is demarked sharply from the posterior surface by a well-developed rim (but never a flange in australites

of the size under consideration). This suggests the possibility of limited ablation having occurred, without accompanying fusion stripping of equatorial regions.

The dumb-bell-shaped cores (text figure 34B) were developed by the frontal ablation of originally rather larger dumb-bell forms of revolution in which the bulbous ends initially had a constant thickness in any one given plane (cf. figure 29, No. 5), and in which the constriction in the waist regions was much less pronounced than in the smaller dumb-bells on which flanges became subsequently developed. Flaked equatorial zones are again characteristic features of most of these dumb-bell-shaped cores. No dumb-bells have yet been observed that would point to any of these forms having travelled through the atmosphere with their long axis parallel with the direction of propagation.

The larger teardrop-shaped cores have a flaked equatorial zone developed in such a way as to indicate that the stable position during flight was like that depicted in text figure 34C. Ablation occurred most dominantly at the front pole of the bulbous portion of the original apioid, and ultimately produced the teardrop-shaped core. A further stage in the melting and flowage of glass from the front polar regions than that shown in text figure 34C, is sometimes one in which secondarily fused glass has become carried around the bulbous end on to the equatorial edge of the posterior surface (cf. Baker, 1946, Plate IX, figures 9A and 9B). In still later stages, more evident with the smaller teardrop-shaped australites, the size of the teardrop has been much reduced by the processes of ablation, and the stage of flange-building has been reached. Here again, it does not seem likely that the teardrop-shaped forms were rotating at any of these stages when secondary features were being produced during atmospheric flight.

The progressive developmental stages in the formation of such secondary shapes as the various round forms of australites from primary spheres of natural glass of presumably extra-terrestrial origin, are indicated in text figure 35.

The posterior surface, shown uppermost in each of the sketches A to H in text figure 35, is regarded throughout as a residual portion of each primary sphere. The anterior surfaces are secondarily developed surfaces arising from the fusion stripping and ablation of the forwardly directed hemispherical half

of the primary form. It is considered that the same general principles apply to the other shape groups, as outlined here for the group of australites that are circular in plan aspect.

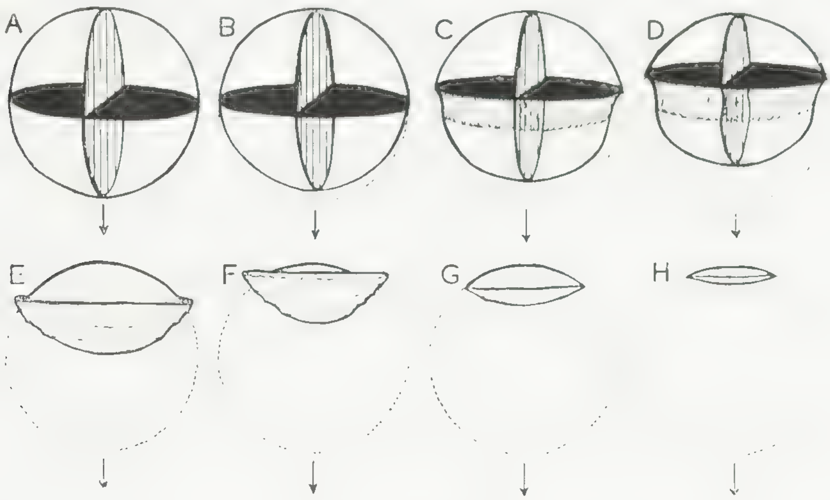


FIGURE 35.

Progressive stages in the development of round forms of australites from primary spheres of australite glass.

A to D—round cores. E to F—buttons. G to H—lenses.

In text figure 35, the spheres from which the cores (or " bungs ") were developed, are frequently twice as large as those from which the button- and lens-shaped australites were produced. The original spheres for the buttons and lenses depicted in text figure 35 had much about the same size range among themselves.

Diagram A (text figure 35) shows a primary sphere, and diagram B depicts initial ablation in its front polar regions. With more ablation and some fusion stripping, a round core of the type shown in text figure 35c is produced, and, at this stage, approximately 10 per cent. to 15 per cent. of the original sphere has been removed. Continued loss of glass melted from the front surface leads to reduction in the size of the core and increase in the radius of curvature of the anterior surface, as indicated by text figure 35D. This process continues with complete loss of the melted glass which becomes whipped away and in part volatilized and dispersed in the wake of the speeding australite body.

Commencing with somewhat smaller spheres of australite glass entering the earth's atmosphere in an originally similar cold condition, ablation and fusion stripping occur soon after

frontal melting has been initiated. This may continue until approximately one half or more of the primary glass sphere has been removed, the condition then being reached at which the remaining solid glass has passed into the requisite size and shape for the onset of flange-building and the development of the flow ridges on anterior surfaces.

The position of separation of the boundary layer flow in the medium (earth's atmosphere) through which each australite body with its modified shape was moving, constantly changed as the arc of curvature of the forwardly directed surface became flatter in character, and as the rim of the form migrated along the front hemisphere backwards from the front polar regions, and beyond the original position of the equator of the primary form. At this stage, the separation of the boundary layer flow from the equatorial edge of these small secondary shapes travelling at ultra-supersonic speeds evidently generates turbulence which becomes responsible for forcing some of the melted australite glass around on to the edge of the posterior surface. As this process is maintained for a while, more glass is piled up in the position indicated, thus leading to the construction of a substantial flange all around the equatorial edge of the object; at the same time there is a marked development of flow ridges on the anterior surface, as in text figure 35F. A somewhat later phase of the process is one in which flange-building glass has been accumulated rearwards to such an extent that the posterior surface of the secondary shape can no longer be seen when the flanged australite is viewed in side aspect, and the majority of flanged australites, as found on the earth's surface, are either of this nature or else reveal a small portion of the posterior surface protruding a short way above the edge of the flange.

Only a narrow contact exists between the flange and the posterior surface of the secondary shape, and much of the flange glass overhangs parts of the edge of the posterior surface without making direct contact (cf. text figure 15). Ultimate loss of some flanges by the combined effects of later stages of ablation, a little fusion stripping and possibly fragmentation during flight, operating more particularly in the " seat " regions (cf. text figure 15), yields the non-flanged lens form depicted in text figure 35G, with its lesser number of flow ridges. Further ablation then reduces this form to the smaller type of lens shown in text figure 35H, or, if conditions are suitable, a small flanged button may be developed. Such small flanged buttons have been found, but it is uncertain

whether they were developed in the manner suggested, or whether some of them were derived from originally much smaller primary spheres which were subjected to comparable processes of ablation.

As an example of the amount of australite glass lost by ablation at the stages indicated by text figures 35E and 35F, the weight of the original sphere of glass from which a flanged button was derived has been calculated as 11 grams, from the specific gravity value of the specimen and the radius of curvature of its posterior surface (i.e. a value that provides the radius of the primary sphere). The separate weights of the flange and of the body portion of this australite are known, so that the amount of glass lost can be determined, thus:

	Per cent.	Weight in grams
Original sphere	100	11·0
Body portion of australite	33·4	3·674
Flange	6·9	0.762
Amount lost	59·7	6·564

It is thus seen that over half of the original glass sphere has been ablated away and nearly 7 per cent. moved around to the rear surface to form a flange. In the same way, it can be calculated that something over 80 per cent. of an original glass sphere was ablated before the residual end product such as a lens of average size was developed.

The causes leading to the generation of flanges on australites have already been discussed as an outcome of the study of the internal flow line patterns of australites generally (under the section dealing with Flow Lines). A few relevant facts remain to be added, from the aspect of the situations of the flanges relative to the primary forms from which australites were developed, and relative to the secondary end products which australite shapes represent.

It is obvious that, because of its steep forward curvature, and its exposure to the greatest amounts of frontal pressure generated during high speed flight, the forwardly facing hemispherical half of a sphere of australite glass (cf. text figure 35A), can provide no stable position for accumulation of fused glass forced away from the front polar regions. The earliest

fused glass would be rapidly whipped away under the influence of drag effects, and, as the process of fusion stripping and ablation progressed, there occurred gradual reduction of the front surface. The radius of curvature of the front surface increased, so that its arc of curvature became flatter (*cf.* text figures 35B, 35C and 35D). The front pole of the original sphere migrated rearwards to within or beyond the region of its original centre before flange-building could commence, for by then, the rim, developed as a secondary feature delimiting the newly formed anterior surface from the remnant portions of the primary rear surface, had passed beyond the former equator of the original sphere. A situation has therefore been produced which is suited to flange-building, for now the equatorial edge of the posterior surface has less steeply sloping backward curvature, so that a more stable position is available for the accumulation of such melted glass as reached and remained in the equatorial regions. Here, under the influence of eddy currents and possibly some friction created by the separating boundary layer flow (*cf.* text figure 36), the secondarily fused, migrated glass began to cool and be moulded into shape. Rapidly following, newly introduced and still warm glass frequently became jammed against the cooler glass already present in the flange regions, causing considerable contortion in some of the flow line patterns of some flanges (*cf.* complex puckering shown in Plate II, Baker, 1944).

It is not yet fully understood why the flange glass in its final form consolidated in a position partially overhanging the equatorial edge regions of the body portion in flanged australites. Possibly, a buffer of reflected air from the cold posterior surface in these regions, was responsible, associated with the viscous state of the glass itself. Evidently the viscous state of the glass was an important factor, for a contrast is provided by rare specimens of australites in which ostensible flange glass was rather less viscous, and instead of building up into a flange structure, it has spread out on to the posterior surface for some distance from the equatorial periphery (in the manner indicated by figures 9A and 9B of Plate IX, Baker, 1946).

The posterior surfaces of flanges were located in low pressure regions during the phase of high speed earthward flight of australites, and these surfaces are characteristically smooth and often slightly concave. On the other hand, anterior surfaces of australites were located in high pressure regions, and their equatorial edges where flanges were built up were positions of

greatest frictional drag; hence the anterior surfaces of the flanges, which are convex generally, reveal complexly wrinkled flow ridges. It is in the " seat " regions of flanges (cf. text figure 15) and from thence to their equatorial edges, that loss of glass is most noticeable as a result of the final phases of the processes producing the end products now representing the secondary shapes of australites. It can be observed from thin sections, that in the anterior surface regions of the flange extending from the " seat " to the equatorial edge, flow lines in the glass of the flow ridges are parallel with flow lines in the immediately underlying glass, whereas the outlines of the intervening flow troughs cut right across secondarily developed, flangeward-trending flow lines (cf. Baker, 1944, Plate III, figure 1), thus indicating removal of thin films of glass from the flow trough regions to rather greater extents than from the flow ridges, during these end stages.

Small bowl-shaped and the disc- and oval-plate-shaped forms of australites, which have not yet been located in the Nirranda Strewnfield, have been discussed elsewhere (Dunn, 1916, p. 223; Baker, 1940*a*, p. 312), but the manner of their origin has not yet been satisfactorily explained in its entirety. These are essentially thin forms of australites, averaging 1 mm. to 1.5 mm., seldom 2 mm. in thickness, and their thickness is out of all proportion to their diameter, the diameters of most forms being 10, sometimes 20 times as great as their thickness. Such forms could possibly be the end products of very small buttons, lenses and ovals that had become so thin by ablation that they were completely softened under the influence of frictional heat, and flattened by frontal pressure to form disc- and oval-plate-shaped australites (cf. Baker, 1946, Plate VI, figures 1 and 2), or even turned backwards where sufficiently unstable, to form bowl-shaped (or " helmet-shaped ") australites (cf. Baker, 1946, Plate VI, figures 3A and 3B). In the writer's opinion, there are no features of these small, thin australites that would indicate the operation of rotational processes during their formation as secondary shapes, even though they seem to have become softened throughout during these end phases of flight, after which they cooled prior to landing upon the earth's surface, at much reduced speeds.

The origin of the shapes of several of the relatively rare aberrant forms of australites that have come under the notice of the writer (cf. Baker, 1946, Plate VII, figures 6A and 6B, Plate VIII, figures 7A and 7B, and Plate XI), can generally be satisfactorily explained by initial reference to modified primary forms

of revolution, some of which may have been accidentally deformed during pre-atmospheric flight and consequently did not behave like the more regularly shaped forms during the phase of atmospheric flight. The aberrant forms of australites are usually of such a type that the idea of rotational motions while passing through the earth's atmosphere seems scarcely tenable.

Viewed on the above basis of the theory of fusion stripping and ablation during high speed flight for the origin of their secondary shapes, certain deductions are herein made concerning the specific gravity values of australites. These deductions seem to give credence to the postulates set out in the foregoing pages. The fact that in any particular australite strewnfield, the smallest australites often have specific gravity values the same as those of the medium-sized and even the largest australites known, and that both lower and higher specific gravity values occur among all sizes, would suggest that complete fluidity of each australite was not attained during atmospheric flight. Had this occurred, it would be expected that more volatile constituents would escape—more being lost from the ultimately smaller, than from the finally larger australites. Since, under such conditions, heavier constituents would be the more volatile, lighter constituents should thus concentrate in the smaller forms, which would then have the lesser specific gravity values (cf. fusion experiments, Baker and Forster, 1943, p. 398). Since this is not shown by the thousands of specific gravity values determined for australites (Baker and Forster, 1943, p. 403), it is concluded that variations in specific gravity among australite specimens of different size, in each separate shape group found from different or the same localities, are essentially a function of their primary phase of formation. During atmospheric flight, progressive fusion and removal of microscopically thin films of melted australite glass from the forward surfaces would not give rise to any really significant specific gravity variation as between the primary form and the ultimate secondary form derived therefrom. It could, however, account for the fact that flanges generally, though not always, have lower specific gravity values than body portions of such of the australites as formed flanges during flight. The flange glass, during secondary melting and migration, possibly lost some of the heavier, more volatile constituents, thus resulting in a slightly more silica-rich residuum with slightly lower specific gravity values.

Effects of Aerodynamical Flow-Phenomena during Ultra-supersonic Flight.

There is every reason to believe that australites are extra-terrestrial objects which entered the earth's atmosphere at cosmical velocities similar to those possessed by iron and stony meteorites. On first reaching the atmosphere, they were evidently cold, non-rotating bodies of glass with complex internal flow-line structures generated in their birthplace. Their speed of traverse through the earth's atmosphere no doubt became progressively lessened as they passed through the increasingly denser lower atmospheric layers nearer to the earth's surface, as a consequence of increased frictional resistance, so that they lost their high cosmical speeds, and fell to earth at speeds controlled by the earth's gravitational forces. The nature of the airflow must have changed considerably and continuously as their speed decreased. No parts of the australites are considered to have been fluid on landing upon the earth's surface.

During transit through the atmosphere at very high speeds, certain aerodynamical factors must have operated in such a way as to produce the known secondary shapes and secondary structures of australites from a small variety of primary forms (cf. Baker, 1944, pp. 18-19).

The rate of fall to earth, at a distance of say 60 to 70 miles above the earth's surface, would be some 6 miles per second if falling due to gravity alone, while the maximum velocity, if at all comparable with that of iron and stony meteorites, would be in the region of 20 to 40, or even 50 miles per second according to various estimates. The time taken to travel through the earth's atmosphere would thus be very short, a matter of a few seconds to a few minutes at most, according to the angle of entry. At such speeds, the velocity of approach of australites to the earth's surface is ultra-supersonic, with a Mach number* somewhere in the region of 27 at the minimum speed of 6 miles per second, some 60 to 70 miles above the earth's surface, and of 192 to possibly 248 as a probable maximum Mach number at the same height. Since, however, the Mach numbers would not be comparable units at these heights as at sea level, because of differences in temperature, pressure and density of the atmosphere at the different levels, they would not be nearly as high as given above, since Mach numbers

* The Mach number (M) is the ratio of the speed of supersonic flow to the speed of sound, so that if M 1.0, the speed of supersonic flow equals the speed of sound, which is 760 m.p.h. at the standard sea level temperature of 15°C. (cf. Black, 1953, p. 252).

decrease in value with increase in height above the earth's surface. Nevertheless, they would still be relatively high and no doubt much greater than those so far attained with guided missiles that have reached supersonic speeds. The guided missiles, which reach heights of up to 250 miles above the earth's surface, and travel at some 2,000 miles per hour, have a Mach number of 2.6, and they travel upwards from denser to less dense layers of the atmosphere. Australites, on the other hand, travel downwards from less dense to denser layers, penetrating all layers of the atmosphere from the most tenuous to the most dense, at speeds which are decreased by frictional resistance of the atmosphere, but which at times are in the vicinity of something between 21,600 and 144,000 to 180,000 miles per hour. Their Mach numbers must therefore be high, even after allowing for decrease in speed with nearer approach to the earth's surface, and also allowing for the fact that Mach numbers fall in value at the greater heights.

Travelling earthwards at ultra-supersonic speeds, the temperature of thin films of the forwardly directed surfaces of spheres, spheroids, apioids and dumb-bells of australite glass, was considerably raised (to at least the softening temperature of tektite glass), by virtue of the development of shock waves ahead of each form (see text figure 36 for a primary sphere of australite glass), for where the air is brought to rest in shock waves, compression is so great as to produce much increased temperatures.

At supersonic speeds, certain important factors come into operation, chief among which are those connected with the aerodynamics of high-speed flow, the behaviour of the air being a function of the relative motion between the atmosphere, which for these purposes can be regarded as virtually at rest, and the australites, which it is presumed must have travelled at very high velocities. To begin with, during supersonic flight, a permanent type of disturbance would be set up in the air piled up ahead of any particular primary form of australite travelling at such speeds, thus creating the important shock waves. Shock waves are regarded as sheets where there exists an abrupt discontinuity of velocity of flow (cf. Durand, 1935), and they are narrow zones of intense compression. The air that flows over the surface of any australite travelling at ultra-supersonic speed, can do so only after it has penetrated the narrow arcuate region of compression known as the frontal shock wave. The frontal shock wave (see text figure 36) travels a short distance in front of the australite, in the same direction at similar speed. Its shape would be broadly

hemispherical, with a radius of curvature a little greater, but otherwise generally conforming with the arc of curvature of the forwardly directed hemispherical surface of the primary australite form, such as the one depicted in text figure 36.

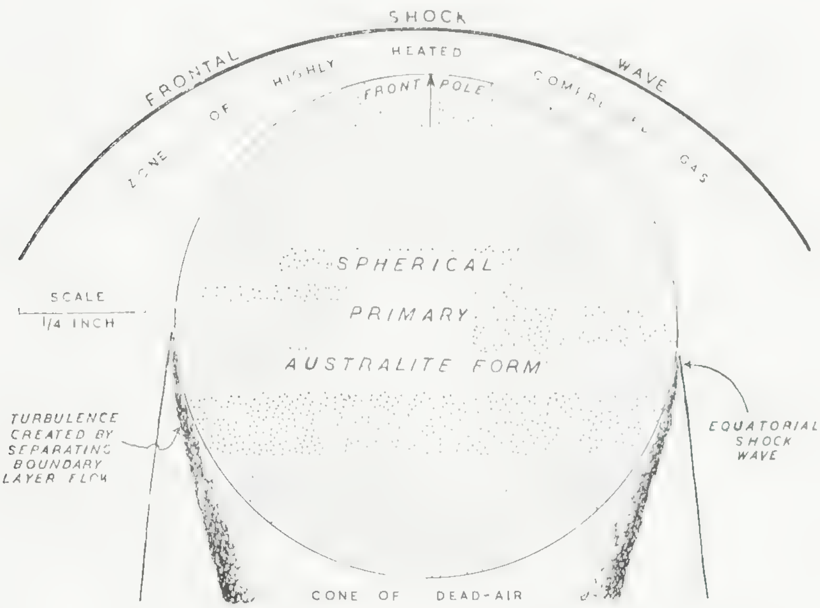


FIGURE 36.

Diagrammatic sectional representation of the probable form and nature of shock waves and turbulent zones created by a non-rotating primary sphere of australite glass travelling earthwards through the atmosphere at ultra-supersonic velocity. (Based on a reproduction by Black, 1953, p. 254).

Along the sides of the primary form, subsidiary shock waves would develop in positions lying obliquely to the direction of propagation, and in them, compression, although high, would probably not be as intense as in the frontal shock wave. For general purposes of illustration, the primary forms of australites are regarded as being initially relatively smooth (cf. text figure 36), and varying in size from 10 to 55 mm. in diameter for spheres, and from 9 x 20 mm. to 40 x 100 mm. for elongated forms. The subsidiary shock waves generated by such forms, are pictured as equatorial shock waves, produced as narrow zones of high compression that lie very obliquely backwards and most likely somewhat detached from the equatorial regions of the sphere (cf. text figure 36) as a result of thickening in the boundary layer of air induced by the objects having such high Mach numbers. The original surfaces of the primary forms of the australites, however,

were no doubt somewhat bubble-pitted, hence the subsidiary shock-wave phenomena would probably be much more complex than indicated in text figure 36.

Behind the fast-moving australite sphere, turbulence is created where the main flow becomes separated in the equatorial regions, by the action of reverse and secondary reverse laminar flow producing vorticity in the relatively thin boundary layers of the atmosphere in contact with the surface of the sphere. It is within the thin boundary layers that all frictional effects arise between the anterior surface of the australite and the fluid medium (the earth's atmosphere) through which it has its trajectory. Thus there would arise stresses in the gaseous medium along the anterior surface of the australite producing skin friction as a tangential component, and stresses in the positions where turbulent flow was generated in equatorial regions producing form drag (Whitlock, 1943, Chapter V). Inside the turbulent wake region, immediately behind the posterior surface, there would most likely exist a cone of virtually dead-air, as indicated in text figures 36 and 37. Its existence enables the posterior surface to be maintained at temperatures well below the fusion temperature of australite glass.

The frontal shock wave constitutes a narrow zone of immense pressure, while behind it, a slightly broader zone extends from the back of the shock wave to the front surface of the primary sphere of australite glass. Although the velocity of the air is decreased in this zone, high pressures, and hence high temperatures persist. A state of steady flow of a permanent type producing shock waves can only be developed when the motion of an object travelling at supersonic or ultra-supersonic speeds, is confined to one direction (cf. Durand, 1935). Therefore it is deduced that there was no major change in the direction of forward propagation of any of the australites that have been recently studied, and there was evidently no rotatory motion.

During the maintenance of shock waves, all the mechanical energy generated at supersonic speed, would be converted into heat, due to the viscosity and conductivity of the air in the zone behind the frontal shock wave. Hence, as long as supersonic speed prevails, a cap of highly heated compressed air travels ahead of the australite, as diagrammatically illustrated in text figure 37.

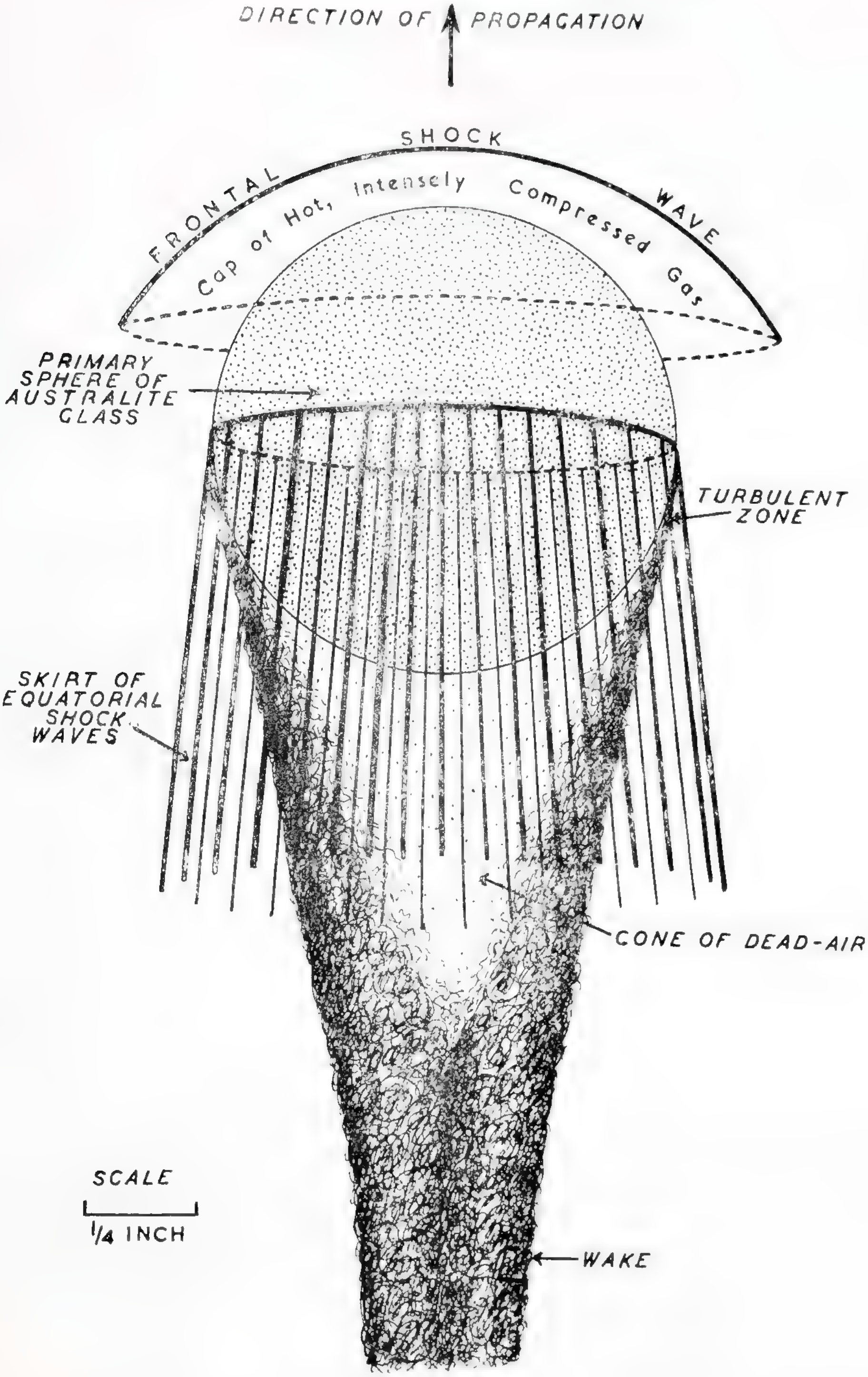


FIGURE 37.

Diagrammatical three dimensional concept of the aerodynamical phenomena of high-speed flow past a primary sphere of australite glass travelling at ultra-supersonic speed.

Under such conditions, during the early stages of development that were eventually to lead to the formation of secondary shapes of australites, this cap of highly compressed air supplied the temperature rise necessary to the softening of thin films of australite glass in the front polar region, where pressures would be greatest. It caused particles of the glass to volatilize, thus initiating the process of ablation that hereafter becomes an important factor in shaping the anterior surface. The cap of compressed air also protected the anterior surface from loss of heat during the very short period of time available for secondary shape development. As a consequence of this process, a proportion of the primary australite forms, most probably the smaller ones, was undoubtedly lost by complete volatilization. Many others, however, survived the effects of the aerodynamical flow phenomena that prevailed throughout the period of maintenance of ultra-supersonic and supersonic speeds, but during their operation, these primary forms became considerably reduced in size and altered in shape, on the forward surface. The separation of the main flow stream from the equatorial regions of the larger primary forms, is regarded as being responsible for the process of fusion stripping that gave rise, on the larger of the forms, to flaked equatorial zones such as are depicted in text figures 33 and 34. In this region occurs the transition zone where laminar flow in the thin boundary layer ends, and turbulence supervenes. The turbulence thus emerges from the thin boundary layer, and being packed with vortices would generate much more intensive form drag.

The final, or near-final, conditions prior to the landing of a button-shaped australite on the earth's surface, are pictured in sectional aspect in Plate VI, figure 28, and in this connexion, reference should be made to Plate I., figure 1, in order to obtain some conception of the character of the frontal aspect of the anterior surface of a button-shaped australite at the end stages of development. At this stage (cf. Plate VI, figure 28), the frontal shock wave is still maintained, although its shape has changed, because the arc of curvature of the anterior surface of the australite has become flatter as a consequence of considerable frontal ablation, hence increasing the angle of the shock waves to the airstream. This change can be judged by comparing Plate VI, figure 28, with text figure 36, where the end stage shown in Plate VI has been derived from a sphere originally the same size as that depicted in text figure 36.

It is known that frontal shock waves lie at various angles to the airstream in supersonic flow (cf. Black, 1953), and with objects travelling at supersonic speeds, these angles are controlled

essentially by the shape of the forwardly directed surface. Since the front surfaces of all the primary and the majority (i.e. flattened forms excepted) of the secondary shapes of australites are never perpendicular to the airstream during their journey through the earth's atmosphere, frontal shock waves would never be generated normal to their path. In other words, during the important formative stages of secondary shape development, the frontal shock waves would always be of the oblique type where pressures, which depend upon deflection, are seldom more than 50 per cent. of the pressures generated when perpendicular shock waves are formed ahead of a perpendicular reflecting surface. Inasmuch as the arc of curvature of the front surface of the secondary shape (cf. Plate VI, figure 28) is flatter than that of the primary australite form (cf. text figure 36), however, the shock wave ahead of the secondary form must be less oblique than that ahead of the primary form, and consequently pressures somewhat greater, and hence drag is more pronounced along the anterior surface. The shape in cross section of the ultimate secondary anterior surface of the australite, is thus not vastly different from that of the isoclinic wings of certain transonic aircraft, as far as the backswept character is concerned. The australite, however, does not have the pointed nose, but this lack would be offset by the greater speeds at which australites travelled.

A few of the smaller australites have been flattened, evidently in the end phases of atmospheric flight, when they had been ablated to very thin forms such as the disc- and oval-plate-shaped examples. If produced at supersonic speeds, then pressures on the front surfaces of such thin forms must have been at a maximum, for their frontal shock waves would have been virtually perpendicular. This may explain why they are flattened and why some of them were even bent backwards into bowl-shaped forms.

In australites with forwardly curved front surfaces, i.e. all other forms, the arc of curvature of the frontal shock wave not only varies with the changing curvature of the ablating anterior surface, but changes also occur in the subsidiary shock waves. Thus the marked skirt of equatorial shock waves of the primary australite sphere (text figure 37) becomes replaced, near the end stages of flight, by a number of flow ridge shock waves, which arise locally around the front surface of the secondary form (Plate VI, figure 28) at positions where the flow ridges slightly project above the general curvature of the anterior surface. These projections, which are situated some distance away from the front polar regions of the secondary shape, and occur at progressively decreasing intervals towards the equatorial edge, are positions

where local accelerated flow arises. Five such projections and their attendant shock waves are illustrated in Plate VI, figure 28 in sectional aspect. Behind each flowridge shock wave, would occur expansion cones of cross section resembling the fan-like expansion regions illustrated by Black (1953, p. 254). Such expansion cones would arise in the flow trough regions, where local scouring-out of glass occurred during these final stages of secondary shape development. The material removed below the level of flow ridges that occur on either side of such flow troughs, is of relatively minor amount, at the most being 0·25 mm. thick from flow troughs nearest the front poles, and 0·40 mm. from flow troughs at the equatorial edge of the secondary shape. Such material was no doubt largely removed as a result of drag in two dimensional boundary layer flow of air in contact with the front surface, for such laminar flow would become an increasingly important factor in the lower, denser layers of the atmosphere, where the secondary shape of the australite received its final sculpturing.

Now Dodwell (see Fenner, 1938, p. 207) has calaculated from Opik's mechanics of meteor phenomena, that friction in the earth's atmosphere would yield a thickness of only 0·001 cms. of liquid film on a medium size australite of 10 mm. radius, and that the temperature difference would be enormous between the surface and the bottom of the film. Moreover, the rate of heat transfer through australite glass is so low that the internal and rear regions must remain relatively cold, this being aided in rear surface regions by the existence of the cone of dead-air. Hence the amount of australite glass in the fused state at any particular instant, must of necessity be small, and it is thus considered to be out of the question that the australite could become completely molten throughout during the atmospheric phase of flight, and yet remain as an entity in itself.

An important result of pressure on the frontal area of an australite moving at ultra-supersonic or even at ordinary supersonic speeds, is the production of drag. This evidently becomes manifest in the thin laminae of contact air during boundary layer flow, where frictional effects are predominant. It is therefore to be expected that the thin liquid film of australite glass produced at any given time during high-speed flight, would be forced away from the place where developed, very shortly after its formation, almost instantaneously in fact, thus exposing a new under-surface of the glass to the heating process—and so the process proceeded

continuously while supersonic speeds were maintained. Particles of liquid glass removed from the frontal area of the australite, where pressures are greatest, would become rapidly volatilized in the highly heated, highly compressed cap of gas lying behind the frontal shock wave, and either swept away into the wake of the speeding australite, or else dissipated obliquely sideways in the region of the lateral flowridge shock waves. As this process continued, the front pole of the original primary sphere receded, the arc of curvature of the front surface became flatter, and the edge of the secondary form constantly moved back and beyond the equatorial zone of the primary sphere. When such a stage was reached, the primary sphere had been reduced to an optimum size and shape where conditions were suitable for the construction of a flange structure, attended by marked flow ridge development and the generation of other subsidiary shock waves. It can be assessed from comparison of the primary sphere indicated in sectional aspect in text figure 36, with the ultimate secondary form indicated by a section through its front and back poles in Plate VI, figure 28, that approximately 60 per cent. to 65 per cent. of the primary sphere has been lost by ablation in attaining the final secondary shape. Not all of the secondarily fused australite glass was lost by ablation and fusion stripping, for some became pushed back to build up the flange, as seen in section in Plate VI, figure 28. During flange growth, turbulence in equatorial regions played an important part in shaping the posterior surface of the flange. Eddy currents operated from the equatorial edge of the flange inwards, at a time in the phases of development when the fusion stripping process that had operated to produce flaked equatorial zones on larger forms (cf. text figures 33 and 34) was no longer a major factor with which to be reckoned on these reduced, originally smaller forms. Near the final stages of secondary shape formation, of which the thin section shown in Plate VI, figure 28 reveals the structure of the end product, the velocity of the australite had considerably lessened, hence pressure and temperature had decreased, and the final act of the now less potent aerodynamical forces, seems to have been a minor amount of scouring in flow trough regions and in the equatorial regions of the anterior surfaces of the flanges, for the australite had by now entered the lower and denser layers of the earth's atmosphere where drag effects were pronounced. The buffeting effects that normally arise from drag and from shock wave formation, were evidently negligible during the formational stages of secondary shapes possessed by australites.

It is considered that the operation of the aerodynamical flow-phenomena, and their effects as outlined above, would be similar for other primary shapes of australites as for the primary sphere utilized in these conjectures. Minor variations may have occurred, although they are not evident from the study of the ultimate secondary shapes produced from different primary forms.

It has already been indicated that the arcs of curvature of shock waves ahead of one and the same australite, would vary and change according to the change in curvature of the anterior surface with ablation. Arcs of curvature of shock waves would also vary from form to form according to the radius of curvature of different primary forms. Moreover, in the smaller number of australites that have the final arc of curvature of the anterior surface steeper than that of the posterior surface, the shape of the frontal shock waves started off steeply curved and hemispherical, then became rather flatter, only to ultimately approach the more steeply curved hemispherical shape again, so that pressure must have oscillated considerably with the varying angle of the deflecting anterior surface to the airstream, being greatest in the intermediate stage, least in the initial and ultimate stages.

In oval-, boat-, canoe-, and teardrop-shaped secondary forms of australites, the frontal shock wave pattern as viewed normal to the polar axes of these forms, would generally parallel the outline of the forwardly directed surfaces, in a similar manner to that depicted (cf. text figure 37) for primary spheres and that for secondary forms (buttons) derived therefrom (cf. Plate VI, figure 28). In dumb-bell-shaped examples, however, it seems likely that two shock wave fronts may have been produced, one ahead of each forwardly directed bulbous portion (cf. text figure 14), so that complexities might be expected in the waist regions ahead of which shock wave interference is surmized.

An important question to be considered in treating of the origin of the secondary shapes as developed during ultra-supersonic flight, concerns the likely temperature values generated in the cap of highly compressed gas ahead of an australite travelling earthwards at high speeds. If australites travelled at 21,600 miles per hour as a probable minimum value, or as much as 180,000 miles per hour as a calculated maximum value, at heights of some 60 to 70 miles above the earth's surface, temperatures should be enormous in the highly compressed cap of gas. On the basis that guided missiles released at the earth's surface, travelling at 3,220 kilometres per hour (i.e. = 2,000 m.p.h.) develop a temperature rise of 1°C. for every 100 Km./hr., their

increased temperature (approximately 300°C.) would be small compared to that computed for australites (2,200°C. to 18,000°C.) by extrapolation. However, temperature values derived in this way, by extrapolation, may have little validity, for the reasons that (*a*) the known temperature rise indicated above may not be maintained, (*b*) australites are not passing through the denser portions of the atmosphere in the earlier stages of atmospheric flight, but in the final stages, and (*c*) at the critical stages of secondary shape formation, speeds may be lower than at a height of 60 to 70 miles above the earth's surface, because of increased drag effects. Hence temperature values in the highly compressed cap of gas could be considerably less than the upper limits given above, but are not likely to be below the lower limits. The temperature necessary to cause solid australite glass to pass into the liquid state, has been determined as 1,324°C. by Grant (1909, p. 447). Therefore the molten film of glass measuring 0.001 cms. produced on the anterior surface of an australite during supersonic flight, must be at least 1,324°C., but since the temperature of melting increases with pressure, the effect of intense compression generated by the formation of frontal shock waves would be to considerably raise the temperature of fusion at ultra-supersonic speeds, so that temperatures at the anterior surface may well have been in the region of 2,000°C. or more. To volatilize this glass during the operation of the ablation process at front surfaces, however, considerably higher temperatures are necessary, so that temperatures equal to the temperature of volatilization of the silicate glass forming australites, must have been attained in the cap of hot, compressed gas behind the frontal shock wave. Because of the opportunity available for reaction between particles of volatilized australite glass and oxygen in this region, certain chemical effects would come into play. Most of the available oxygen would evidently be consumed during volatilization, so it is not to be expected that outer oxidized films of glass would be extensively or continuously produced on the front surface of the australite itself. Such oxidized films are never found on the outer surfaces of australites on discovery, although they can be produced by heat treatment under certain conditions in the laboratory. Thus, a flange fragment and a body fragment from different australites in the Port Campbell Strewnfield, also a small button-shaped form with flange remnants (reg. no. E845) from the Nirranda Strewnfield, all developed reddish-brown skins after heating them to 1,200°C. for two hours under atmospheric pressures in an oxidizing atmosphere, in an electrically heated tube furnace. The oxidized film of glass so produced, was exceedingly

thin, measuring under 1 micron, and microscopic examination revealed that no particular strain phenomena had become evident in the glass immediately below the film. At this temperature, softening of the glass had just become initiated in one place, indicated by sticking at a point of contact between the australite glass and the containing silica boat. The reddish-brown, thin oxidized film had a marked satin-like lustre, and its colour is due to the complete conversion of ferrous to ferric iron in the outer skin of australite glass.

If any such oxidized films tended to develop on the highly heated front surfaces of australites during ultra-supersonic flight downwards through the earth's atmosphere, they were evidently rapidly removed by the effects of drag in the laminar boundary layer flow along the anterior surface. Now since the flange glass of australites represents material moved from front polar regions to equatorial regions, at certain phases of development of the secondary shapes of australites, then flanges are the places to seek evidence for the possibility of front film oxidation having occurred. Thin sections of some three dozen flanged australites, reveal that the flange glass in the majority is always the same colour as the body glass, and moreover, in the body glass itself, there is no colour difference between posterior surface regions, anterior surface regions or central regions. In two examples of flanges, however, (cf. Baker, 1944, p. 12 and Plate II, figures 1 and 9) a limited amount of banding of deep brownish colour is present. Dunn (1912, p. 6) also noted occasional colour differences in the flanges of australite sections he described. These bands can only indicate that some oxidation of the front film had occurred, and that only in a few examples was this oxidized glass incorporated with the non-oxidized glass which forms the bulk of the flanges.

Since it appears logical to assume that australites travelled through the earth's atmosphere at greater than ordinary supersonic velocities, all the processes outlined above in forming secondary from primary shapes, must have occurred in a very short period of time. Thus, if their fall was vertical through the atmosphere, the primary forms of australites suffered frontal melting, fusion stripping and ablation, and flange-building processes, and were developed into the secondary shapes as we find them upon the earth's surface, all in a matter of 10 to 15 seconds, if travelling at the upper speed limits of 40 to 50 miles per second, or a matter of 1½ minutes at the most at the lower speeds of 6 miles per second, (not allowing for the slowing down effects of

transit from more tenuous upper atmosphere to more dense lower atmospheric layers). If their path of fall was oblique, the time taken would be approximately up to three times as long, according to the angle of entry into the atmosphere. During their high speed flight, high compression in the air ahead of australites produced high temperatures which operated for a very short period of time, and so opportunities were rather limited for oxidation to occur in thin films of fused glass, hence only meagre evidence exists to indicate that a small measure of oxidation did arise in these thin films.

CONCLUSIONS

The evidence revealed by a detailed study of the Nirranda Strewnfield australites, together with the accumulated results of observations carried out on approximately 2,000 australites from the south-western Victorian region, indicates that australites need not have rotated during their short periods of rapid translation through the earth's atmosphere.

Apart from the spheres, which are essentially non-rotational bodies, the other primary forms from which some secondary shapes of australites arose were certainly produced by rotation, since the evidence indicates initial generation of typical forms of revolution from rotating molten bodies of glass. The birthplace of the primary forms was undoubtedly extra-terrestrial.

On entering the earth's atmosphere, and at that stage possessing the low temperature equivalent to that of outer space, the onset of conflict of the primary glass bodies with the earth's atmosphere, through which they travelled the greater portion at ultra-supersonic speeds, generated pressure and frictional heat in the front regions of each object. This was insufficient to produce complete melting throughout, but was adequate to result in sheet fusion and thus progressive frontal melting of thin films of glass. If any of these glassy bodies entered the earth's atmosphere initially rotating, which is very doubtful, then they evidently lost their spinning motion very quickly, and continued along their line of flight at ultra-supersonic speeds, until slowed down near the earth's surface, by which time some had become completely evaporated, and the remainder became very much modified in shape. Glass melted from their anterior surfaces was thus not whirled away by rotational forces, but was forced back under pressure and the influence of frictional drag from the front polar regions towards the equatorial regions of each non-rotating body.

Much glass was completely lost in this way from the greater number of the separate primary bodies, assisted by the agencies of rapid fusion stripping and ablation, until the shapes of australites, as they are now known, were developed.

The final secondary shapes of australites show several marked stages in the progressive operation of these processes. Larger forms show flaked equatorial zones, but no flanges and no flow ridges. Medium sized forms have developed flanges at certain specific sizes and shapes, and with them, concentric, anticlockwise spiral or clockwise spiral flow ridges on anterior surfaces only. Smaller forms mostly lost their flange, largely during flight, but some as a consequence of subsequent sub-aerial erosion.

Microscopic complete forms of australites have never been found, although searched for among the materials upon which australites of macroscopic size have been discovered. It is not likely that microscopic australites will ever be discovered, because complete dissipation by ablation seems to have occurred, both of all the glass melted from front surfaces during the generation of the secondary shapes (allowing for that retained in equatorial regions as flanges), while all forms below a specifically limited lower size value have also been completely ablated. It is to be expected that after any particular primary form had been ablated down beyond a certain minimum size, it completely evaporated, for the reason that ablation depends essentially upon the size of the surface, and that with diminishing volume, the relative size of the surface increases. In a similar, but not quite identical way, raindrops that reach the earth, have a certain minimum size. The smallest known complete australite is one from Port Campbell, Victoria (see Baker, 1946, Plate VI, figure 1), which weighs 0.065 grams and measures 9 x 6 x 1 mm. It is doubtful if complete australites less than 0.05 grams in weight are ever likely to be found.

The majority of known australites have been further modified by erosion while they lay upon the earth's surface, some to greater degrees than others, and many have been fractured by various causes. Some specimens have been so much more affected by erosion than others, that sometimes they scarcely appear at first to belong to the australite fraternity. These later modifications to the secondary shapes of australites must always be carefully considered, particularly where the smaller cores (body portions) are concerned, before a final decision can be made regarding their original primary form and their subsequent secondary shapes.

As found upon the surface of the earth, australites have evidently passed through the following principal stages:

(A) Initiation, some as spheres, some as primary forms of revolution, in an extra-terrestrial environment.

(B) Secondary modification of the primary forms by virtue of their short periods of flight at ultra-supersonic velocities through the earth's atmospheric envelope.

(C) Tertiary modification of the secondary shapes by the relatively prolonged action of terrestrial agencies after landing upon the earth.

As extra-terrestrial bodies that have passed through the whole thickness of the earth's atmosphere, the symmetrical Australian tektites must have experienced velocity reductions of a very marked degree, in a sequence from initially ultra-supersonic, through supersonic and transonic, to ultimately subsonic, in a very short period of time, before coming to rest upon the surface of the earth. Their secondary shapes were impressed upon them in the early to intermediate stages, at speeds greater than transonic speeds.

ACKNOWLEDGMENTS

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DESCRIPTION OF PLATES

Plate I.—(x3).

Figure 1—Anterior surface of complete button-shaped australite (E1016)* showing counter-clockwise flow ridge and tendency to radial arrangement of flow lines outwards from the front pole. Coll. E. D. Gill.

* Numbers so given are registered numbers in the Rock Collection of the National Museum of Victoria.

Figure 2—Posterior surface of complete button-shaped australite (E1016) showing bubble-pitted surface of core and finely etched surface of flange.

Figure 3—Posterior surface of flat, lens-shaped australite (E736), the second smallest complete form in the Nirranda Strewnfield australite collection. Coll. G. Baker.

Figure 4—Posterior surface of naturally detached, almost complete flange (E835) from a button-shaped australite. Coll. G. Baker.

Figure 5—Posterior surface of a smaller, naturally detached complete flange (E962) from a button-shaped australite. Coll. G. Baker.

Figure 6—Posterior surface of incomplete button-shaped australite (E928) that has lost approximately one third of the flange. Coll. M. K. Baker.

Figure 7—Posterior surface of lens-shaped australite (E876) showing narrow superficial groove extending from equatorial to polar regions. Coll. A. E. Gill.

Figure 8—Anterior surface of incomplete button-shaped australite (E847) with flange remnants and concentric flow ridges, and showing deep groove extending approximately three parts across the form. Coll. E. D. Gill.

Plate II.—(x3).

Figure 9—Anterior surface of hollow button-shaped australite (E1052) showing crudely radial arrangement of deep grooves. A hole at the front pole where several of the grooves unite, leads to an internal cavity. Note concentric flow ridge. Coll. R. T. M. Pescott.

Figure 10—Posterior surface of hollow button-shaped australite (E1052) showing two remnants of flange and bubble-pitted, irregularly flow-lined surface of core.

Figure 11—Broken posterior surface of hollow button-shaped australite (E816) indicating size of internal cavity and showing small remnants of a narrow flange. Breakage was natural, by impact or by weathering. Coll. G. Baker.

Plate III.—(x3).

Figure 12—Posterior surface of oval-shaped australite core (E961) showing bubble pits. Coll. G. Baker.

Figure 13—Side aspect of oval-shaped australite core (E961) showing flaked equatorial zone between posterior surface (uppermost) and anterior surface (lowermost).

Figure 14—Side aspect of conical core (E1109) showing strongly flaked equatorial zone. (This form is round in plan aspect). Coll. E. D. Gill.

Figure 15—Posterior surface of australite core (E860) showing bubble crater situated in smoother flow-lined swirl having crudely counter-clockwise spiral flow lines, and surrounded by finely bubble-pitted glass. Coll. A. M. Gill.

Figure 16—Side aspect of oval-shaped australite core (E922) showing well-developed flaked equatorial zone with small grooves and pits. Pres. Mrs. A. Mathieson, Snr.

Plate IV.—(x3).

Figure 17—Posterior surface of canoe-shaped australite (E809) showing bubble pits. Drawn-out bubble pits and flow lines occur at the narrowed ends. Coll. M. K. Baker.

Figure 18—Side aspect of canoe-shaped australite (E809) showing recurved ends.

Figure 19—Anterior surface of canoe-shaped australite (E809) showing smoother surface and concentric flow ridges.

Figure 20—Posterior surface of dumb-bell-shaped australite (E761) showing small bubble pits and fine flow lines parallel with long axis of slender form. Coll. A. E. Gill.

Figure 21—Oblique view of one side of posterior surface of boat-shaped australite (E785) showing deep grooves (" saw-cuts "). The grooves continue around the anterior surface to the opposite edge of the posterior surface. Coll. A. E. Gill.

Figure 22—Posterior surface of teardrop-shaped australite (E744) showing minute pits and flow lines. The flow lines at the bulbous end (bottom of photograph) are counter-clockwise spiral, and extend along the length of the form to the narrow, flange-like end (top of photograph). Coll. A. E. Gill

Figure 23—Posterior surface of oval-shaped australite (E759) showing bubble pits and flow pattern. Coll. A. E. Gill.

Figure 24—Side aspect of artificially etched oval-shaped australite (E710) showing flow lines and vitreous lustre where etched, and dull portion in polar regions of posterior surface (top of photograph) where non-etched. Note partially developed flange. Coll. E. D. Gill.

Figure 25—Anterior surface of artificially etched oval-shaped australite (E710) showing vitreous lustre and minutely etch-pitted pattern.

Plate V.—(x7).

Figure 26—Thin section of lens-shaped australite (E749) showing internal flow-line pattern. Coll. A. E. Gill. (Section taken through front and back poles; posterior surface uppermost.)

Figure 27—Thin section of lens-shaped australite (E932) taken at right angles to that shown in figure 26, showing internal flow-line pattern. Coll. M. K. Baker. (Section taken through equatorial plane.)

(These two thin sections are radial and equatorial sections respectively, of two lens-shaped australites of the same specific gravity and similar depth.) (Note swirls and complex " fold-like " flow pattern.)

Plate VI.—(x5).

Figure 28—Thin slice of button-shaped australite with flange, from Port Campbell, Victoria, showing relationship of front (anterior) surface to surmized aerodynamical flow phenomena created during ultra-supersonic flight, and relationship of back (posterior) surface to turbulence phenomena.

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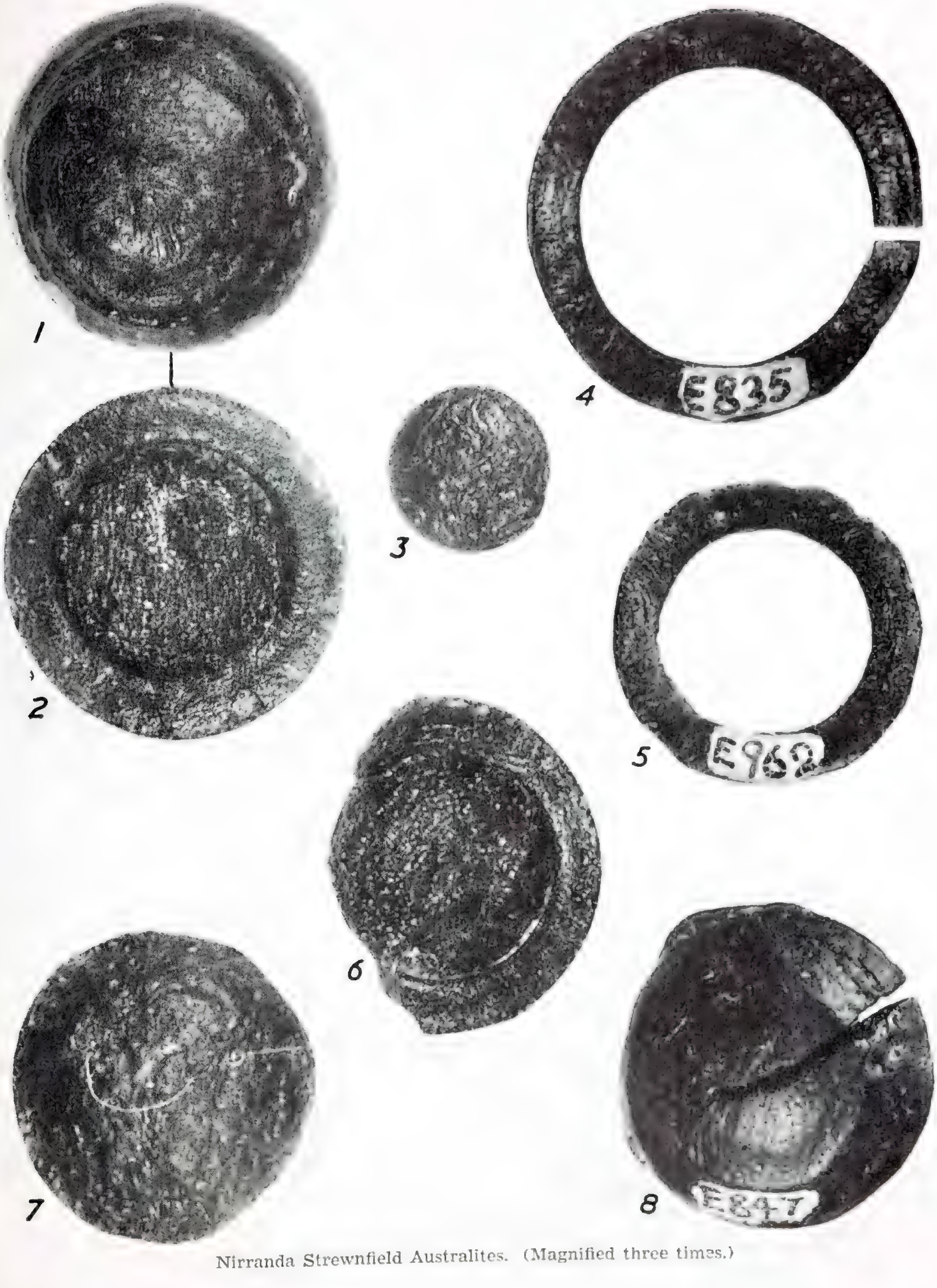
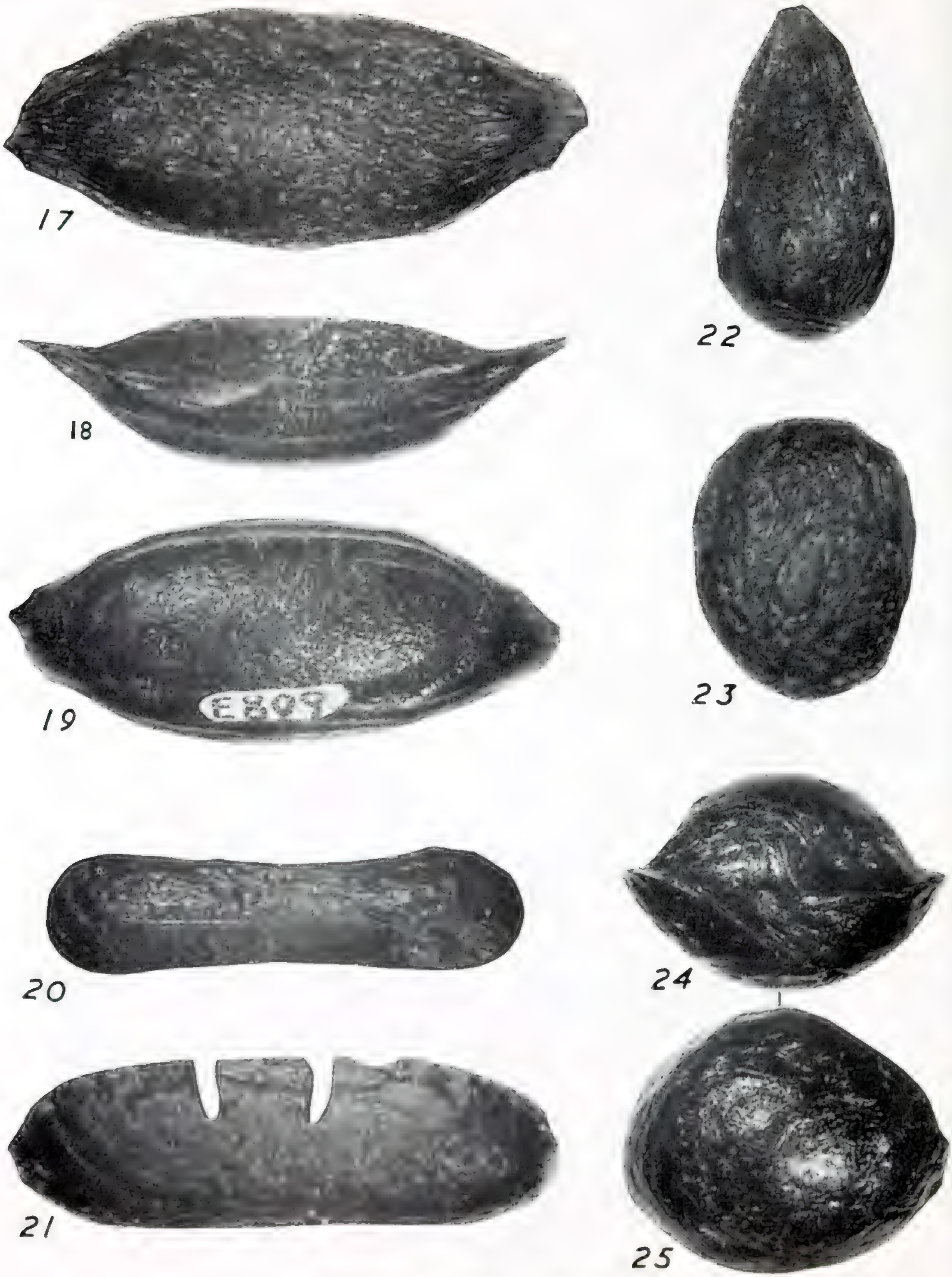


Nirranda Strewnfield Australites. (Magnified three times.)

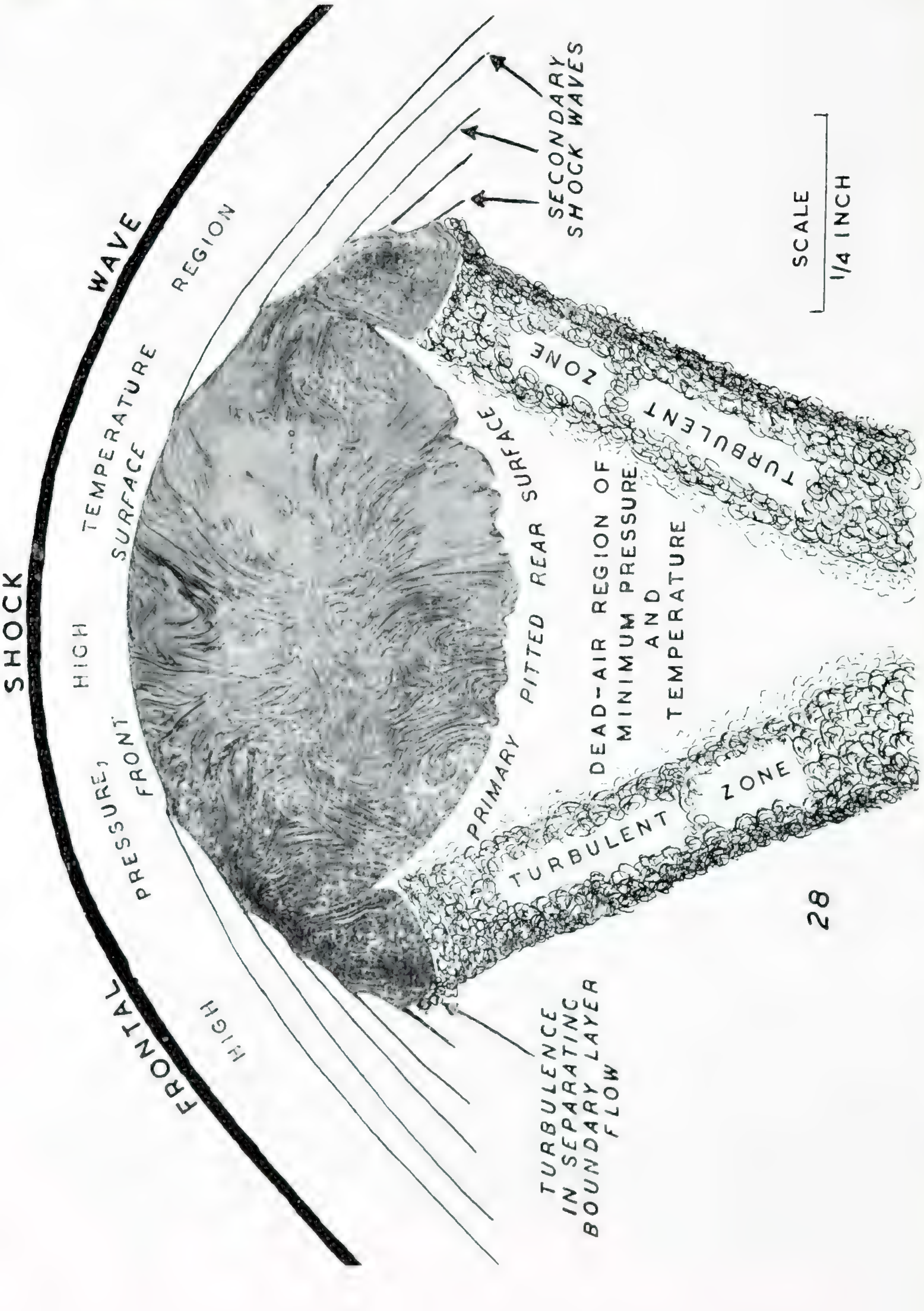
Nirranda Strewnfield Australites. (Magnified three times.)

Nirranda Strewnfield Australites. (Magnified three times.)



Nirranda Strewnfield Australites. (Magnified three times.)

Flow Structures in slices of Nirranda Strewnfield Australites. (Magnified seven times.)



Supersonic Flow Phenomena in Relation to Australite.

NATURAL BLACK GLASS RESEMBLING AUSTRALITE FRAGMENTS

By George Baker, M.Sc.

Searches for australites in south-western Victoria, have revealed a number of fragments of materials superficially resembling australite fragments. They were found on some of the less vegetated areas that lie scattered along 50 miles of a narrow coastal strip between Moonlight Head and Childers Cove.

Most of these fragments are readily determinable as non-tektitic, but several are natural black glass fragments (Plates I and II) that have been rather puzzling and required laboratory tests to provide the ultimate proof of their true nature.

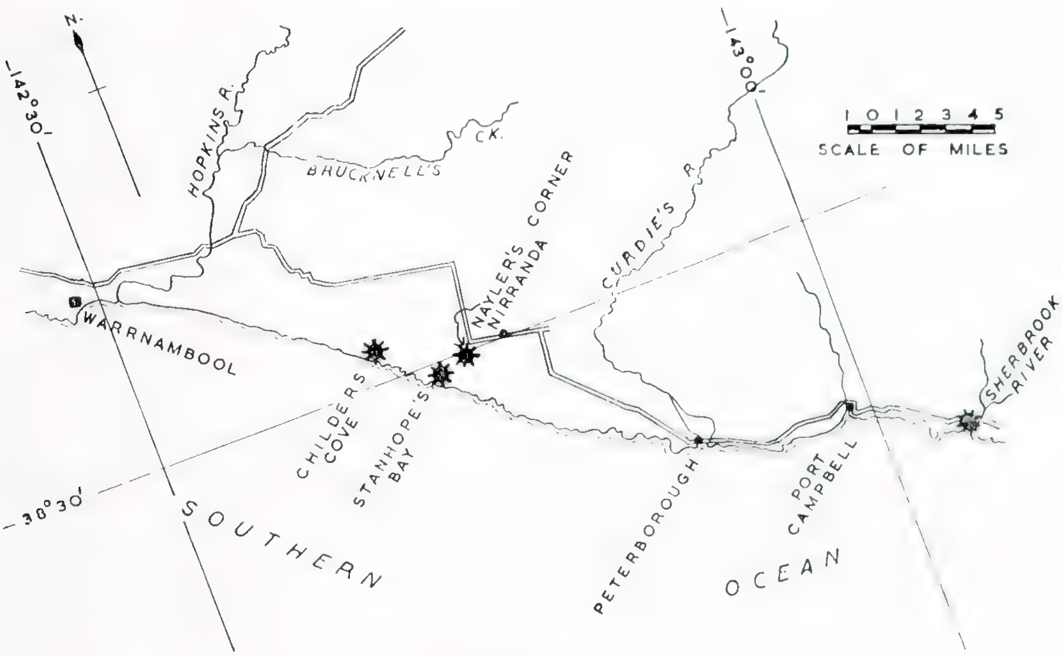


FIGURE 1.

Sketch map of the south-west Victorian coastline from Warrnambool to the Sherbrook River, showing sites (*) of natural black glass fragments.

Fragments of this black glass were located in 1934 on the west bank, near the mouth of the Sherbrook River in the Parish of Waarre, 3½ miles south-east of Port Campbell township (Parish of Paaratte), County of Heytesbury. Additional fragments were located in 1953 by Mr. R. T. M. Pescott, by Mr. E. D Gill and by the author in the Childers Cove district, 23 miles west

of the Sherbrook River site. Black glass localities in the Childers Cove district are (i) near Childers Cove itself, (ii) at Stanhope's Bay $2\frac{1}{2}$ miles south-east of Childers Cove, and (iii) on the roadside, $\frac{3}{4}$ mile south of Nayler's Corner. These localities, shown in text fig. 1, are all in the Shire of Warrnambool, County of Heytesbury.

The fragments of black glass collected from these localities, are lodged in the National Museum Collection, Melbourne (reg. nos. E1115 to E1151), and twelve other fragments are registered in the Melbourne University Geological Collection (reg. nos. 2958 to 2969).

Chemical analysis has revealed that the black glass is of basic to intermediate composition. It occurs as irregular small fragments on the surface of a wind-swept and rain-washed old soil horizon of geologically recent age, that has been bared of the youngest soil layer and of vegetation on a number of small patches along and near the coastline. On the surface of such exposed areas, the black glass fragments have been found associated with occasional pellets of buckshot gravel, aboriginal flints, aboriginal midden shells and australites at each of the three principal sites of discovery, namely at the mouth of the Sherbrook River, at Childers Cove and at Stanhope's Bay.

The relative rarity of the black glass fragments and their peculiar external sculpture (Plates I and II), are noteworthy features. Fifty-three fragments have so far been collected. Their glassy character, black colour and the resemblance of certain of their external surface sculpture features to some of those shown by several types of the glassy, but acidic, tektites from various parts of the world, raised the question of the possibility that these peculiar black glass fragments might indicate the presence of tektites more basic than usual.

The main object of this paper is to show that in its more essential characteristics such as chemical composition, specific gravity and refractive index, the black glass is most likely non-tektitic, and seems to be of terrestrial origin, inasmuch as it is more specifically allied to the glassy tachylyte which is associated with terrestrial basic volcanic activity. Moreover, the fragments never reveal any remnants that would point to derivation from such symmetrical shapes as those possessed by the Australian tektites. The densely black colour, vitreous nature and resemblance of certain sculpture elements, thus combine to provide an entirely fortuitous set of circumstances causing these black glass fragments to resemble australite fragments. The chemical composition fairly

closely approaches that of some tachylytes, while the specific gravity and refractive index values can be closely matched with the most glassy portions of some of the known Victorian tachylytes; in fact, these properties are identical with those of one example of tachylyte. A similar surface pattern to that on the black glass fragments, however, has not yet been observed on fresh or weathered specimens of black tachylyte examined from Victoria, although comparable surface features do occur on some specimens of green and blue tachylytic material lodged in the National Museum, Melbourne.

Description.

The black glass is brittle, non-magnetic, harder than orthoclase (H = 6) and just scratched by quartz (H = 7). It does not fuse under the blowpipe, and tends to spall readily under prolonged heating. Freshly fractured surfaces are vitreous and have strongly marked conchoidal fracture (Plate II, figures 14–18), sometimes with a pronounced secondary ripple fracture (Plate II, figure 15) on the curved surfaces, as in broken

TABLE I.

Black Glass Fragments.	Sherbrook River.	Childers Cove.	Stanhope's Bay.	¾ Mile South of Nayler's Corner.	Australites.
Number of specimens ..	20	6	26	1	Several thousand
Range of weight in grams	0·49 to 4·05	1·06 to 2·96	0·26 to 9·80	..	0·06 to 218·0
Average weight in grams ..	1·92	1·87	2·0	0·21	1 to 2
Range in specific gravity ..	2·67 to 2·81	2·80 to 2·83	2·66 to 2·83	..	2·31 to 2·51
Average specific gravity ..	2·78	2·81	2·80	2·79	2·41
Refractive Index ..	1·575	1·575	1·575	1·575	1·488 to 1·520
Total weight in grams ..	38·40	11·22	51·40	0·21	Several thousand

australites. Weathered surfaces are duller and the partially worn secondary ripple fracture marks on some such surfaces (Plate II, figure 16), then bear some resemblance to certain flow patterns on weathered tektites.

Table I shows the number of black glass fragments discovered at each locality, together with their weights, specific gravities and refractive indices. Most of the weight and specific gravity values (sp. gr. determined at 20° C.), were determined on an air-damped balance, by Mr. G. C. Carlos. The values for australites generally, are appended to the list for comparison.

For a total weight from all localities of approximately 101 grams, the average weight of the 53 black glass fragments is 1·91 grams, and the calculated average specific gravity 2·79. The mode in the frequency polygon (text fig. 2) is 2·80.

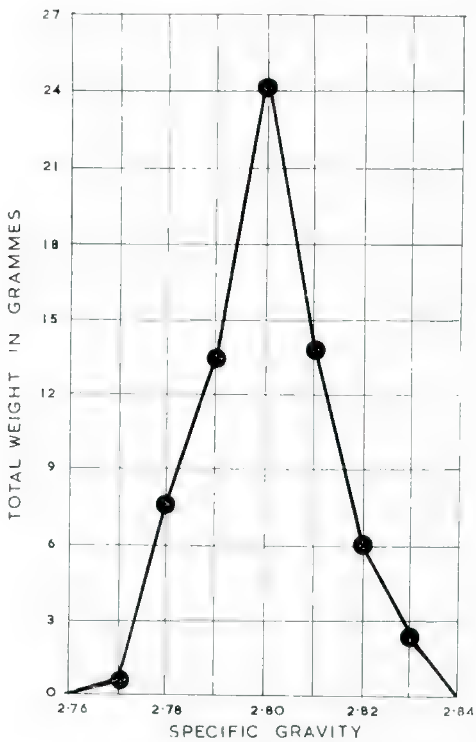


FIGURE 2.

Frequency polygon showing weight—specific gravity relationships in black glass fragments.

In comparison with the above values, the specific gravity of the most glassy piece of tachylyte located during a search of part of the caldera rim of Tower Hill, 7 miles north-west of Warrnambool, has been determined as 2·79, a value comparable with the general run of specific gravity values of the black glass fragments. Away from included crystals, the refractive index (1·575) of the darker parts of this piece of Tower Hill tachylytic glass, is

identical with that of the black glass fragments. There are, however, marked differences in the chemical compositions of the two (cf. Table II), because the analysis of the Tower Hill specimen is of a rock composed of part glass and part crystals, the analysis of the black glass fragments is of a glass virtually free of crystals. A specific gravity value for tachylyte from Meredith, Victoria has been determined as 2·83 by Hall (see Dunn, 1914, p. 324), and another for tachylyte from a basalt quarry near Geelong, Victoria, was recorded as 2·74 by Skeats (1915, p. 336).

In contrast to australites, it can be seen from Table I and the black glass fragments have considerably higher specific gravity and refractive index values.

The colour of fresh fracture surfaces of the black glass is an even, dense black over the greater part of all specimens. The only exceptions are certain ring-like structures of glass that are embedded in the black glass (Plate I, figs. 7 and 8) and are greyish in colour.

Apart from colour similarity and vitreous character, the sculpture features that impart to the black glass fragments their superficial resemblance to fragments of certain tektites are (*a*) aggregated bubble pits (Plate I, figs. 1 to 6), and (*b*) ring-like structures (Plate I, figs. 3, 7, and 8), which on weathering, sometimes resemble the " höfchen " and " tischchen " structures found on some specimens of tektites. The characteristic external and internal flow-line patterns of tektites, however, are not present in the black glass. The distribution, diameter and depth of the bubble pits on some pieces of the black glass, are closely similar to those of bubble pits on the fractured and weathered surfaces of certain specimens among several of the different varieties of the tektites, in particular surfaces that are not as crowded as normally with bubble pits.

The combined " höfchen " (" little haloes ") and " tischchen " (" little tables ") structures (Plate II, figs. 13, 16, and 19), are similar in shape and arrangement to allied structures that have been variously referred to in tektite literature as " lunar craters ", " navels " and " ring marks." Such structures have been described more particularly from billitonites (see text fig. 3), moldavites and rizalites, and are rather rare on australites.

The " höfchen " are ring-like in plan (text fig. 3B) and are essentially circular grooves of U-shaped cross section surrounding an elevated central portion or small island called

" tischchen " (cf. text fig. 3A). On the black glass fragments from south-western Victoria, the " höfchen " structure is frequently occupied by brownish-grey coloured glass, and the grooves only become evident after the weathering out of this material. Where unweathered, the brownish-grey glass exposed

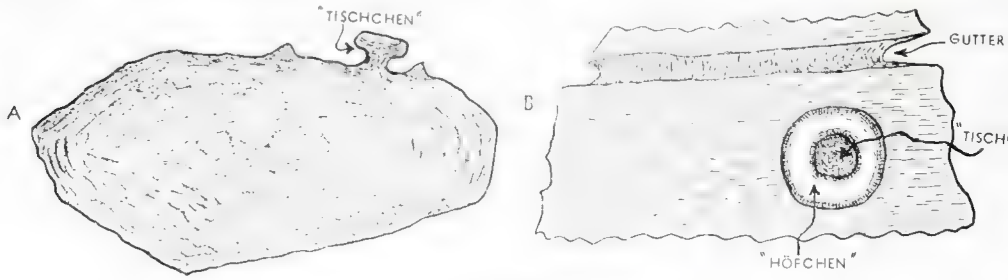


FIGURE 3.

Figure 3—Diagrammatic representation of " höfchen " and " tischchen " structures on billitonites.
A—side aspect of " tischchen " on an irregularly-shaped billitonite.
B—enlarged portion of billitonite showing plan aspect of " navel " (= circular groove or " höfchen "), surrounding an island of glass (= " tischchen ").
Magnification = x4.

on the surfaces of the flatter fragments, lies on much the same plane as the adjacent densely coloured black glass, and the structures resemble rings (Plate I, figs. 7 and 8), being thus similar to the appearance in thin section, as depicted in text fig. 4.

The " höfchen " and " tischchen " structures only become evident and accentuated as the brownish-grey glass is removed by weathering from the ring-like structures, thus leaving a circular, sometimes an elliptical groove having a surround of black glass on its outside, and an island of black glass within its inside curvature (see Plate II, fig. 19).

Fracture planes lying in three directions approximately at right angles to one another, reveal that the " ring marks " represent cross sections through what are virtually spherical to spheroidal shells of brownish-grey glass containing central cores of intensely black glass. These structures are in turn embedded in black glass identical with that of the cores enclosed by the shells of grey glass.

Such structures are of interest, inasmuch as a distinctly marked second type of glass has not been recorded from the " höfchen " structures of tektites. The grey glass shells in the black glass fragments weather more rapidly than the black glass. Chemical changes involve oxidation to a reddish- and brownish-coloured clay-like substance, sometimes quite hard, but frequently relatively

soft and hence readily removed by etching and by mechanical processes, leaving the circular and elliptical grooves. Occasionally, in thinner fragments of the black glass, the whole shell of grey glass may thus be removed, the central core of more stable black glass falls away, leaving a hole (Plate II, fig. 17). The external dimensions of the shells of grey glass vary from 0·05 mm. for those that are spherical, to 9 x 14 mm. for those that are spheroidal. The range in thickness of the walls of the shells of grey glass is from 0.010 to 0.750 mm.

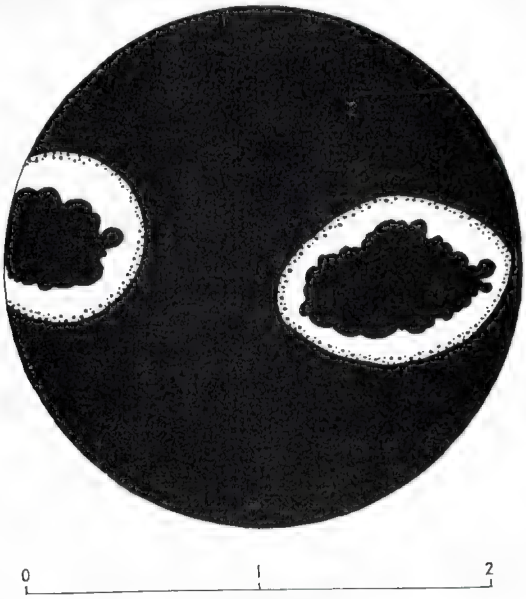


FIGURE 4.

Figure 4—Sketch of black glass as it appears in thin section. Rings of grey-coloured glass are embedded in densely coloured black glass. Small spherules of black glass are embedded within the "ring" glass, near the outer walls of the shells. Specimen from the Sherbrook River, near Port Campbell.

The surfaces of the "tischchen" are usually smooth in smaller examples (Plate II, fig. 19), bubble-pitted or irregularly roughened in larger examples (Plate I, fig. 5).

Most of the "ring marks" observed on the flatter fracture surfaces (cf. Plate I, fig. 7), are commonly isolated from one another. Less frequently they have coalesced into figure-8 shapes, and very rarely they are arranged in short chain-like structures composed of three or four links. A few of the smallest of the "ring marks" do not form complete shells of grey glass, the partially enclosed core of black glass being in contact with the surrounding black glass at two or three points, thus revealing disconnected crescent-shaped areas of grey glass as observed in sectional aspect.

The black glass fragments take an excellent polish, and examination of polished surfaces under the reflection microscope, reveals no opaque minerals. Etching in acids and thin section studies reveal no internal flow-line patterns.

It is impracticable to grind the black glass sufficiently thin to observe translucency with ordinary methods of illumination, since there is a tendency for the development of numerous fine, hair-like fracture lines separating the glass into small polygonal areas which break away only too readily with further grinding. The use of a concentrated beam of artificial white light, however, reveals reddish-brown colours in the thinnest parts of the densely coloured glass, while the greyish-brown shell glass takes on a yellowish- to brownish-grey colour and in parts shows strain polarization effects. These characteristics are markedly different from tektites, all varieties of which are evenly translucent in both thin sections and in thicker plates even under ordinary conditions of illumination, showing greenish- to brownish-yellow colours. Finely ground particles of the intensely black glass fragments, mounted in refractive index liquids and examined in daylight with the high power condenser of the petrological microscope inserted, show a smoky brownish- to reddish-grey colour on their thinnest edges. The glass on the whole, however, is remarkably opaque under normal conditions.

In thin sections, the lighter coloured glass of the "ring marks," and the intensely black glass within and around these structures, are generally quite free of crystals, thus indicating a homogeneous glass, since flow lines are also absent. The refractive index of the shell glass is 1·550, that of the black glass is 1·575. The only signs of the onset of crystallization, are extremely rare and very poorly marked. They can be observed under powerful artificial illumination in thin section of one only of the black glass fragments, where the largest of the cores of black glass within a shell structure, contains feathery skeletal crystals that weakly affect polarized light, but are indeterminate. The effect of their presence in this core, is to impart a crude radiating structure (Plate II, fig. 9) as observed in the hand specimen prior to sectioning.

A feature of the grey glass forming the shells of the spherical and spheroidal structures, is the presence of included small spherules of the intensely black glass that are invariably confined to positions close to the outer walls of the grey glass shells, as depicted in text figure 4.

Comparison with known Victorian tachylytes.

The usual types of tachylyte encountered in Victoria, are not nearly as vitreous as the black glass fragments discussed herein, and they generally show a microcrystalline to glassy structure under the microscope.

Examination of a collection of unusual and rare types of variously coloured tachylytes lodged in the National Museum Rock Collection, Melbourne, reveals that some of the specimens possess certain features similar to those displayed by the black glass fragments, thus further substantiating the tachylytic nature of these fragments. Bubble pits on iridescent tachylyte from the Mt. Shadwell quarry, near Mortlake, and on greenish-brown tachylyte from Mount Warrenheip, near Ballarat, are similar in size, shape and distribution to those on the black glass fragments from south-western Victoria.

A specimen of tachylyte from Sunday Creek, near Tallarook (reg. no. 1581 in the National Museum Rock Collection), contains black, brownish-green, bluish-green and blue coloured areas of tachylyte all " welded " together in the one hand specimen. The areas of black glass occur as spherulitic patches with a finely radiating structure, while portions of the brownish-green, bluish-green and blue areas contain small spherules of the black glass. Some of these small spherules are enveloped in grey glass, as in parts of the black glass fragments under discussion, and where weathered, similar " höfchen " and " tischchen " structures have been produced. The blue and bluish-green colours in this specimen, are evidently due to a small content of nickel and cobalt, or possibly to manganese and titanium (cf. analysis of the bluish tachylytic glass from Meredith, Victoria in Table II, column 3).

Other specimens of tachylyte in the National Museum Collection, obtained from the Corporation Quarries at Clifton Hill, from Broadford, Mirboo North, the Barwon River near Geelong, Meredith, the Werribee River, Mount Elephant and Mount Warrenheip, are all markedly vitreous, but most specimens differ from the black glass fragments in showing either occasional nests of crystals, or else occasional micro-crystals distributed throughout the glass. These specimens vary in colour from black, through brown, brownish-green, greenish- and brownish-yellow, but none of them have identity with the black glass fragments described herein. Very rare fragments of a greenish-grey coloured tachylyte resembling similarly coloured specimens in the National Museum Collection, have been found on the same rain-washed, wind-swept patch of ground near Stanhope's Bay where some of the black glass fragments were collected.

Confusion of the black glass fragments with tektite fragments.

Glassy specimens showing green, blue and reddish-brown colours similar to the colours of the tachylyte specimens referred to above, have been found in parts of Queensland, and have been referred to (Richards, 1934, and anon., 1937) as tektites. The writer has not seen these specimens, but their description is considered to be more applicable to coloured tachylytes which are known in the colours mentioned, rather than to tektites, accepted varieties of which are not known to have these colours.

Similarly coloured specimens of natural glass described from the Philippine Islands (Beyer, 1940), from Colombia in South America by Stutzer, and from Czechoslovakia by Suess and others, have sometimes been referred to as pseudo-tektites, and may well be tachylytes of similar colours to those mentioned above.

That tachylytic material was confused previously with australites and with obsidian in Victoria, becomes apparent from the following remarks. An early publication (Ulrich, 1875, p. 35) contains a description of obsidian as occurring " at Geelong, Ballarat, and in the crater hills and plains of the Western District; in the latter localities generally in small, button-like pieces and sometimes larger balls, hollow and glazed in the centre. A black, pitchstone-like mineral, probably tachylyte, has been found at Phillip Island." These " small, button-like pieces and larger balls " were later called " obsidianites " and are now universally referred to as australites.

The specimens of glass from Geelong, were described by Selwyn and Ulrich (1866, p. 65) as obsidian occurring in patches and irregular veins of an inch or more in thickness. Later, Dunn (1914) quoted some old analyses of the Geelong " obsidian," claiming that these analyses and others, proved there was acidic volcanic glass in Victoria, similar in composition to that of australites. Skeats (1915), however, showed that the analyses were unreliable, as Walcott (1898, p. 32) had already indicated, and that the so-called " obsidian " from Geelong was actually tachylyte (Skeats, 1915, p. 333) and contained globulites, trichites and scattered phenocrysts of olivine, augite and plagioclase felspar which are unknown in true tektites. It was thus the petrological work of Skeats (1915) that ultimately revealed the true character of black glass specimens which earlier had been confused with tektites. Since then, there has been little chance of confusing such specimens with tektites, as long as it could be shown that they were crystal-bearing by the use of thin sections and the petrological

microscope. The black glass fragments under discussion in this paper, however, could still be confused with tektites, for so many of them reveal no vestiges whatsoever of globulites, trichites, microlites, crystallites or micro-phenocrysts of any mineral. Hence thin section studies have to be supplemented by specific gravity and refractive index determinations, and sometimes by resort to chemical analysis, in order to prove conclusively that they are in no way connected with the extra-terrestrial bodies of glass referred to as tektites.

Confusion of these black glass fragments with tektites, moreover, is even more likely to arise by virtue of the fact that they were found upon the same bare patches of ground as undoubted tektites (australites), in an area remote from the usual volcanic associates of tachylyte.

Chemical Composition of the black glass fragments.

Several typical specimens of the black glass fragments, totalling 8·2 grams in weight, were selected from the Stanhope's Bay site for the purposes of chemical analysis, and an analysis was also made of the most glassy piece of tachylyte that could be located on Tower Hill caldera, near Warrnambool. These analyses are compared in Table II with tachylytes previously analysed from Meredith, Victoria, and from Inverell, New South Wales, and with an average composition of australites.

The silica content of the tachylyte from a basalt quarry near Geelong, was determined by Walcott (1898, p. 32) as 53·2 per cent. A partial analysis by A. B. Edwards in 1935, of black glass fragments from the mouth of the Sherbrook River, 3½ miles south-east of Port Campbell, reveals close similarity with the black glass fragments from Stanhope's Bay. The SiO_2 content of the Sherbrook River example is 52·90 per cent., while $CaO = 6{\cdot}00$ per cent., $MgO = 3{\cdot}39$ per cent., and $TiO_2 = 1{\cdot}27$ per cent.

The chemical composition of the black glass fragments is comparable with that of the Meredith tachylyte and the Inverell tachylyte, but is rather more acidic than the Tower Hill tachylyte, and in no way comparable with the average composition of the much more acidic australites. Moreover, the black glass has a SiO_2 content up to 17 per cent. greater, an alumina content seven times greater, and a lime content four times greater than the opaque pseudo-tachylyte (cf. Barnes, 1940, p. 648) found as veins up to over one inch thick in meteorites, while there is much less

MgO, FeO, NiO and CoO. In addition, the specific gravity of meteoritic pseudo-tachylyte is 3·51 to 3·73, which is much higher than the average (2·79) for the black glass fragments discussed in this paper. There is thus little likelihood that the Victorian black glass fragments have come from the thicker veins of pseudo-tachylytic material found in some stony meteorites.

Table II, columns 1 and 2, show that the black glass fragments contain approximately 5 per cent. more SiO_2 than the somewhat glassy, but largely microcrystalline tachylyte from the caldera rim

TABLE II.

	1.	2.	3.	4.	5.	6.	7.
SiO_2	52·82	47·54	50·87	51·68	54·76	53·86	74·0
Al_2O_3	14·93	13·69	14·33	14·77	16·49	15·41	12·8
Fe_2O_3	2·08	1·87	5·37	1·26	0·80	1·50	0·5
FeO	9·78	10·53	7·25	10·70	10·71	11·51	3·9
MgO	3·37	7·99	4·51	4·67	3·57	3·60	1·9
CaO	6·80	8·56	8·22	8·37	7·89	7·18	3·0
Na_2O	3·54	3·12	3·39	2·61	2·67	3·04	1·0
K_2O	2·33	3·02	1·35	2·52	2·03	1·24	1·9
H_2O (+) ..	1·10	0·13	0·17	0·13	0·59	1·10	0·3
H_2O (−) ..	Nil	0·06	0·33	0·01	0·11	0·44	
CO_2	Nil	Nil	..	Nil	..	..	..
TiO_2	2·67	2·91	3·38	2·91	n.d.	0·36	0·5
P_2O_5	0·24	0·26	0·07	0·26	0·32	0·35	..
MnO	0·34	0·33	0·58	0·33	n.d.	0·16	0·1
NiO + CoO ..	..	..	0·06	..	..	..	..
Cl_2	tr.	tr.	str. tr.	0·12	..	..	..
Total ..	100·00	100·01	99·88	100·34	99·94	99·75	..
Specific Gravity ..	2·823*	2·849*	2·831	..	..	..	2·41†

* Specific gravity determined in the powdered state (− 100 B.S.S.) at 20°C.
† Average specific gravity of 1,086 australites.

KEY

1—Black glass fragments (crystal-free) from Stanhope's Bay, 15 miles south-east of Warrnambool, Victoria. (Anal. G. C. Carlos.)
2—Tachylyte (crystal-bearing) from southern rim of caldera, Tower Hill, near Warrnambool, Victoria. (Anal. G. C. Carlos.)
3—Bluish coloured glassy portion of tachylyte, Meredith, Victoria. (Anal. A. G. Hall—see Dunn, E. J. *Rec. Geol. Surv. Vic.*, III., pt. 3, p. 324, 1914.)
4—Tachylyte, near slate quarry, allotment 55, Parish of Meredith, Victoria. (Anal. A. G. Hall, *Ann. Rept. Sec. Mines, Vict.*, 1910, p. 64.)
5—Tachylyte, Inverell, New South Wales. (See *Ann. Rept. Dept. Mines, N.S.W.* (1898), p. 187, 1899.)
6—Tachylyte, Inverell, New South Wales. (Anal. W. A. Greig—see *Ann. Rept. Dept. Mines, N.S.W.* (1912), p. 198, 1913.)
7—Average composition of australites from various localities in Australia.

of Tower Hill. The formation of this rather more acidic tachylytic glass, evidently lies in the early separation of rather more basic crystals from the parent (terrestrial) basic magma. These crystals would be floating in a molten groundmass having a generally more acidic composition than either that of the already formed crystals, or that of the magma as a whole. Separation of the crystals, probably by a process of local sinking, followed by rapid cooling of the residuum, produced a black (iron-rich), homogeneous glass showing practically no signs of further crystallization, and containing some 5 per cent. more silica and considerably less MgO than crystal-bearing tachylytic glass such as the Tower Hill example (Table II, column 2). The mode of formation of the small greyish-brown coloured shells of glass (which are a little more acidic again), embedded in black glass, is problematical.

Remarks and Conclusions.

On first appearance, the fragments of black glass described herein, are more readily mistaken for fragments of australites than are any other materials found in searches for tektites in several of the australite strewnfields of south-western Victoria. As well as being vitreous and equally as black in thick fragments, the glass sometimes shows bubble-pitting similar to that of some australites, and also shows the "höfchen" and "tischchen" structures so typically developed on certain varieties of the tektites. Photographs of portions of two australites have been included in the accompanying plates (see Plates I and II), in order to give some idea of the close resemblance in the hand specimens of the black glass fragments and tektite fragments.

Detailed examination, involving the preparation of thin sections and polished surfaces, the carrying out of chemical analyses, and the determination of refractive index and specific gravity values, finally proves that the black glass in question does not come into the same category as the acidic tektites with their ubiquitous and unique, complex internal and external flow-line patterns, different chemical composition, and lower specific gravity and lower refractive index values. Features which do show some resemblance to certain features of tektites, are therefore only pseudo-tektitic features.

The black glass fragments evidently come from a rare and special type of tachylyte, formerly gathered by the keen-eyed aborigines from a source as yet unlocated by us, and possibly prized by them for some particular purpose. It is known that

the aborigines used tachylyte for implements (*fide* Mr. S. R. Mitchell), but the black glass fragments referred to herein, appear to be merely chips that were not worked for any special purpose, as they show no signs of aboriginal secondary chipping. They might well have been employed for ceremonial or other purposes, however, and so would be collected by the aborigines and carried for some considerable distance from their natural source. The aborigines are known to have utilized "emu-stones," consisting of australites and other black stones resembling them, in one of their emu-hunting methods, and evidently it did not matter to them whether the black stones were australites or fragments of black tachylytic glass, as long as they were densely black and possessed a vitreous character and some degree of rarity. It is also known that these black stones ("emu-stones") formed a considerable proportion of the gizzard stones of large native birds. Thus it seems highly likely that the fragments of black glass were left by the aborigines, along with chipped flakes from other types of rocks, also grinder stones, &c., on areas close to large kitchen middens and camping grounds which are of frequent occurrence along these parts of the south coast of Western Victoria.

Whether or not these fragments became buried under surface soils at one time or another, their exposure over a considerable period of time, on barren patches of ground that are now much wind-swept and rain-washed, has led to the accentuation of their bubble-pitted structures and the etching out to varying degrees of the less stable greyish-coloured glass in the "ring marks", thus producing tektite-like sculpture on black vitreous material.

The origin of the bubble pits evidently lies in gas bubbles escaping through glassy basic lava that was rapidly chilled, but the origin of the grey glass shells with enclosed cores of black glass, which on weathering ultimately gave rise to structures resembling the "höfchen" and "tischchen" structures on tektites, is a matter for considerable speculation. The lighter coloured glass of the "ring marks" has a lower index of refraction than the neighbouring black glass, thus reflecting a slightly different chemical composition, the most marked variation in which seems to be a lower iron content and a higher silica content. The refractive index of the greyish-coloured glass ($n = 1 \cdot 550$) being significantly lower than that of the densely black-coloured glass ($n = 1 \cdot 575$), indicates that it is rather more acidic, for it has been shown (Spencer, 1939, p. 425) that refractive index decreases with increased silica content in natural glasses. Having a lower refractive index value than that of the

black glass, and hence suspected of being more acidic, the specific gravity of these grey-coloured shells would also be less, since the specific gravity of natural glasses also decreases with increased silica content. The shells of grey glass would thus be somewhat lighter than their cores of enwrapped black glass and their external surround of similar black glass. It would appear, therefore, that the grey glass shells represented bubble walls of lighter glass that had incorporated some of the denser black glass, and was suspended and partially dispersed in heavier black glass. The mode of formation of such shells of slightly different glass, however, at present remains a mystery.

The fragments of black glass have been subjected to minor amounts of natural flaking by sub-aerial agencies, during their period of exposure on an exhumed former soil horizon. This is indicated by the presence of quartz grains jammed into many of the circular and elliptical grooves, and into some of the bubble pits, added to which there has been some cementation of fine sand and clay constituents into similar positions. Differential expansion and contraction during diurnal changes of temperature (changes that would be very marked on the naturally bared patches where the fragments were discovered), would set up strains and stresses tending to weaken parts of the glass, ultimately causing spalling away of small fragments. Several specimens reveal evidence of minor fracturing that can be ascribed to such a series of events.

Acknowledgments.

The writer is indebted to Mr. E. D. Gill for help in many ways, and to Mr. G. C. Carlos for carrying out the specific gravity determinations and two chemical analyses. The photographs were prepared by Mr. L. A. Baillôt at the Melbourne Technical College.

Description of Plates

Plate I. (x3).

Figure 1—(E1119)*, showing bubble pits and bubble craters, one small and one large of the "höfchen" and "tischchen" structures.

Figure 2—(E1131), the largest fragment observed, irregular in shape and showing single and nested bubble pits, craters, occasional small "höfchen" and "tischchen" structures within and outside the craters, and groove containing altered shell glass extending from large "höfchen."

Figure 3—(E1138), showing bubble pits, several small "höfchen" and "tischchen" structures, groove with altered shell glass, and conchoidal fracture.

Figure 4—(E1118), showing larger "tischchen" with papillate and minutely pitted surface, surrounded by "höfchen" containing grey shell glass.

Figure 5—(E1117), side aspect of figure 9 (Plate II), showing large "tischchen" with irregular roughened surface (top of photograph) and ripple fracture marks. Smaller weathered "höfchen" and "tischchen" structure in left centre of photograph.

Figure 6—(E1146), showing vitreous lustre and group of medium size bubble pits ornamented with the wall remnants of smaller bubble pits.

Figure 7—(E1116), flat surface of a fracture fragment, showing broken "höfchen" and "tischchen" structures appearing as elliptical and circular "ring marks."

Figure 8—(E1136), sliced and polished surface, showing elliptical "ring mark" composed of grey shell glass (equivalent to "höfchen" structure), surrounding core of black glass (cf. "tischchen" structure), the whole structure being embedded in black glass.

Plate II. (Nos. 9–18 magnified three times; No. 19 magnified fifteen times).

Figure 9—(E1117), a different aspect of figure 5 (Plate I) showing crudely radiating arrangement on surface of large "tischchen," due to incipient crystallization.

Figure 10—Portion of australite (E847) with groove and part of flow ridge, included for comparison with figure 11.

Figure 11—(E1145), showing deeply etched groove, few small bubble pits and a ridge formed by the junction of two fracture surfaces.

Figure 12—Portion of australite (E961), showing bubble pits; included for comparative purposes (cf. right-hand side of figure 18).

Figure 13—(E1133), showing occasional "höfchen" and "tischchen" structures, and three pits (in line trending north-east) from which both the shell glass and the core glass of the "höfchen" and "tischchen" structures have been removed.

Figure 14—(E1150), showing conchoidal fracture of densely black glass, and groove with weathered shell glass (on right).

Figure 15—(E1127), showing vitreous lustre on fresh conchoidal fracture surfaces having subsidiary ripple fracture.

* Numbers so given are registered numbers in the Rock Collection of the National Museum of Victoria.

Figure 16—(E1125), showing flatter fracture surface with three small, well-developed " höfchen " and " tischchen " structures (cf. figure 19).

Figure 17—(E1151), showing weathered, slightly convex surface of conchoidal fracture fragment from which one " höfchen " and " tischchen " structure has been removed leaving a hole; others have been removed to leave pits.

Figure 18—(E1144), the smallest fragment observed, showing minutely pitted surface (cf. figure 12) and conchoidal fracture surfaces.

Figure 19—(E1125), enlarged portion (x15) of figure 16, showing small " höfchen " and " tischchen " structures.

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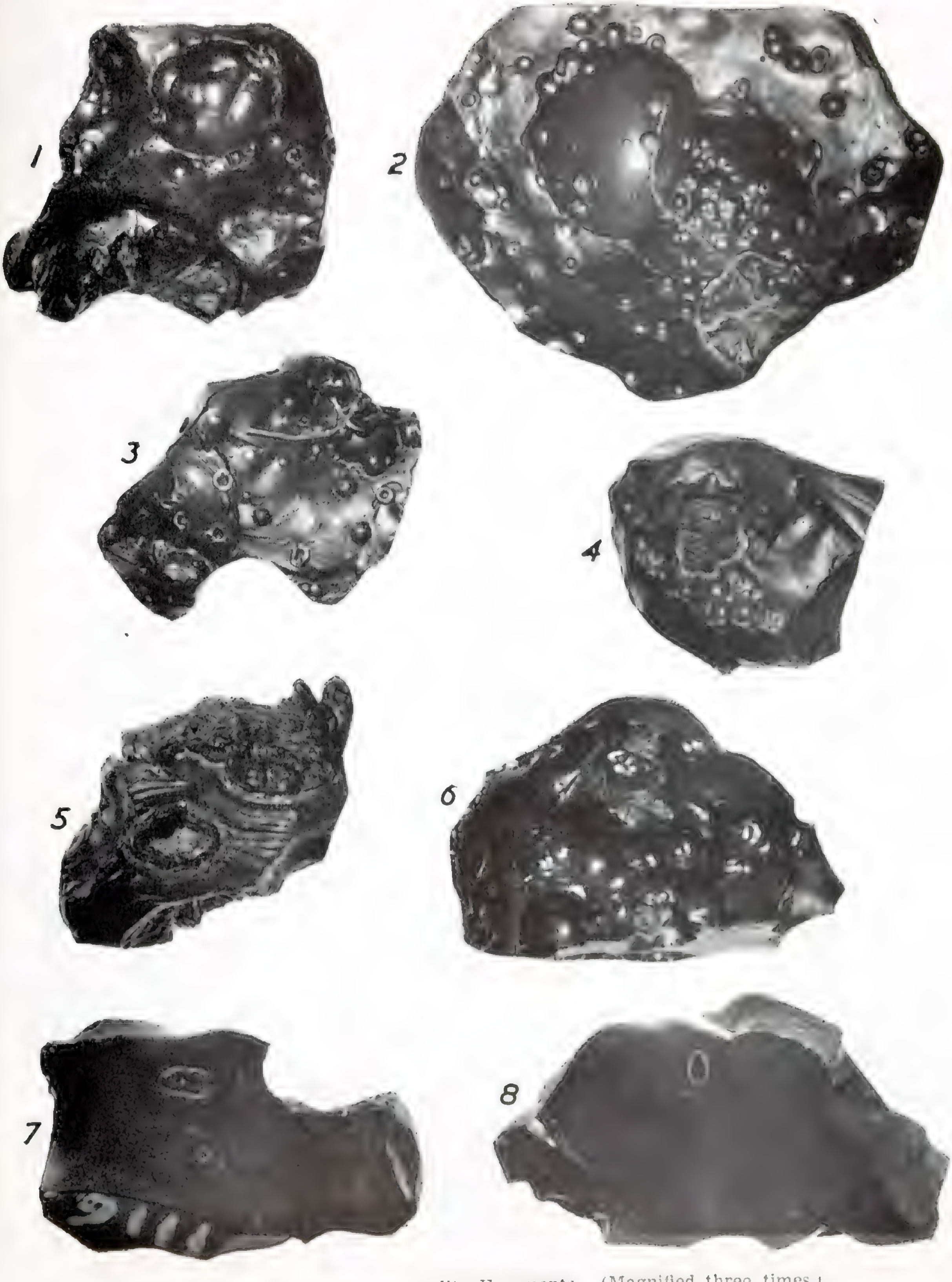
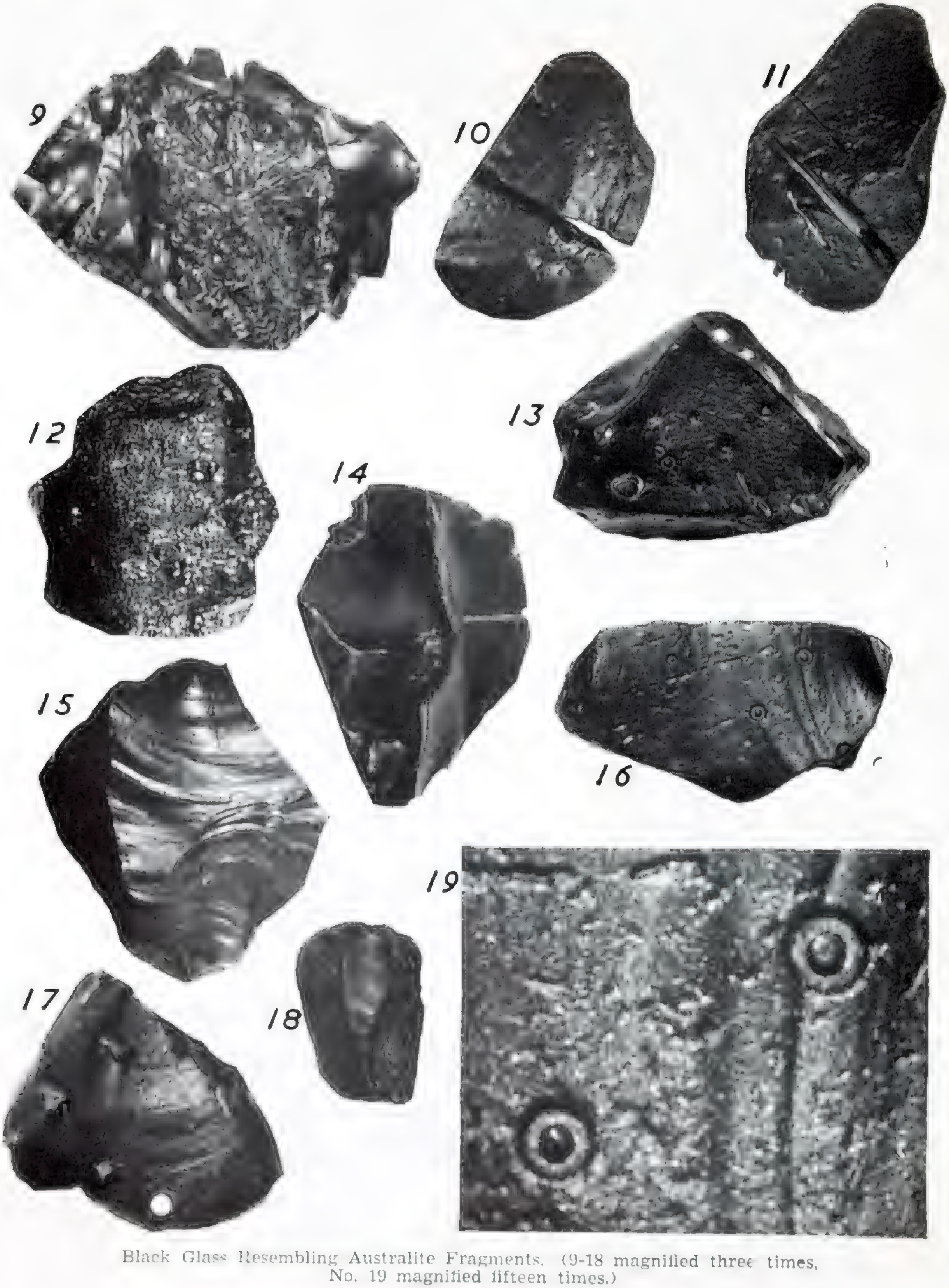


Black Glass Resembling Australite Fragments. (Magnified three times.)



Black Glass Resembling Australite Fragments. (9-18 magnified three times, No. 19 magnified fifteen times.)

MISCELLANEOUS NOTES ON THE CULTURE OF THE TASMANIAN ABORIGINAL

By the late A. L. Meston[1]

Drinking Bowl

A bowl formed from a skull cap was found on June 20, 1929, on a midden close to a spring of sweet water at Port Sorell, north coast of Tasmania. Its size and shape, together with the situation where it was found, suggest that it was used as a drinking bowl.

The bowl consists of parts of the frontal and parietal bones of a human skull (Plates A-C and fig. 1). It is not symmetrical, more of the right side of the skull-cap being present than the left, so that the sagittal suture is about 1.5 cm. nearer to the left margin of the specimen. The lip of the bowl passes behind the frontal eminences anteriorly and through the lambda posteriorly; on the (anatomical) left side it passes just above the parietal eminence, being closer to the sagittal suture, and on the right side below the eminence, being farther from the sagittal suture.

The sagittal and coronal sutures are well marked externally and faintly internally, characteristic of the bone condition of a young adult. The amount of bone remaining in the bowl is too small for definite racial classification of the skull, but there is little doubt that it is non-European and the features present are moreover in conformity with those of an aboriginal Tasmanian skull—external keeling towards the sagittal suture, post-coronal hollowing (more marked on the right side), relative absence of antero-posterior curvature in the frontal region, and increased width in the region of the parietal eminences.

The greatest length of the bowl is 150 mm.; the greatest width is 130 mm., in the region of the parietal eminences. The natural shape of the bones also means that the bowl is a little deeper

1. This paper has been prepared from manuscript notes by Archibald Lawrence Meston, who died in Hobart on December 21, 1951. He was an authority on the Tasmanian aboriginal. Meston's extensive collection of Tasmanian stone implements and other materials was recently acquired by the National Museum of Victoria.

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N. J. B. Plomley.

posteriorly than anteriorly. The rim is irregular. The outer table of compact bone is lacking around part of the rim, principally on the frontal (Plate C and fig. 1), and the clear cut line along which this occurs suggests that removal of bone here may have been part of the process of shaping the bowl, to provide a thinner edge for the lips in drinking at the shallow anterior end. On the other hand the possibility that weathering might account for the erosion of bone cannot be excluded.

The Tasmanians, not having learnt to make pottery, found great difficulty in carrying water to their encampments. Shells were used but shells of a size sufficient to carry any quantity are rare in Tasmania. Labillardiere tells us that the women and girls brought water to the men who sat near their fires, using for the purpose vessels of sea-weed. Others describe similar vessels. Allan Cunningham, who visited Macquarie Harbor with Captain King in 1819, tells us that the natives he met, greatly prized bottles because they were so useful for holding water, calling such a vessel *moka*. The bowl here described is another most interesting *moka*.

A few examples are known of the use of skulls as water-vessels by other peoples, both contemporary and historic. There are several records of such use by the natives of south-eastern Australia. The skulls were either left more or less complete and provided with a carrying handle, or were reduced to a deep skull cap formed by the parietal bones and the greater part of the frontal and occipital bones; the sutures were made watertight with gum (*vide* Davidson, 1937). Three examples of these skull-vessels are in the Australian Museum. In Europe the use of skull-caps for drinking vessels is known for Magdalenian times. The vessel here described is unique so far as Tasmania is concerned; it resembles the roughly shaped Magdalenian bowls rather than the carefully prepared mainland Australian aboriginal vessels.

Bone Implements

Up to the present the only Tasmanian aboriginal bone implements recorded have been the four specimens described by Crowther (1925, 1926). Noetling (1912) had earlier dealt with the question of the use of bone by the Tasmanians in the manufacture of implements but he considered there were no authentic instances of its use.

A much larger collection of bone implements is now available for study, collected by me on field trips over the last twenty years. From the same localities have also been collected many pieces of broken bone, large points and " spatulas " chiefly (Plate D); these fragments may have been used casually just after the whole bone was broken but do not show any working or other evidence of special shaping, or any wear.

The implements now recorded are of two distinct types, points and spatulas, and all are formed from parts of the long bones of mammals and, in one case, a bird.

Points or Awls.

These implements fall fairly clearly into two groups—

(*a*) broad points and (*b*) needle points.

(*a*) *Broad points* (Plate E).

The three examples of broadly pointed tools do not resemble each other closely. One (110 mm.) is larger than the others and has been made from a fragment of a long bone (? tibia of wallaby), with one end ground to a broad point (*a*). The two smaller specimens are both about 64 mm. long but otherwise have little resemblance (*b* and *c*). Specimen *b* is the upper part of the radius of a mammal (? wallaby), the shaft being ground obliquely to a broad point. Specimen *c*, on the other hand, is a fragment of a long bone of a bird, chipped and then ground to a broad point at one end and with the other end chipped to a roughly rounded shape. Both ends of this latter implement show much wear by use. The large cross section and thin wall of the fragment are suggestive of bone structure in the herons, of which group the " Blue Crane " (*Notophoyx novaehollandiae*) is fairly common in Tasmania.

Specimens *a* and *c* were found in the Rocky Cape midden and *b* at Tiger Creek.

(*b*) *Needle points* (Plate F).

This series of points differs from the preceding group in that the point is long and rounded rather than short and broad. The implements have the form of awls or skewers and in two cases (*c* and *d*) are particularly sharp.

All the implements have been made from the upper end of the fibula of a kangaroo or wallaby, except in one case (*a*) where an ulna has been used (the point being ground obliquely down the shaft). The working end of the tool is formed from the shaft

and the grip from the end of the shaft and swollen terminal mass of bone (the epiphysis is not present, apparently having dropped off). The point has been formed by grinding, a long sharp needle-like implement being produced.

The lengths of the four longer implements range from 159 mm. to 190 mm., and of the three shorter ones from 91 mm. to 117 mm. (tips broken). Fibulae of the three Tasmanian Macropodidae have apparently been used in making these points, those of *Macropus tasmaniensis* in the largest, those of *Thylogale billardieri* in the smallest and the intermediate sizes made from fibulae of *Wallabia rufogrisea frutica.*

The specimens were found at Arthur River, south side (*c, e,* and *h*); Bottle Creek (*b* and *d*); Rocky Cape midden (*a*); and Tiger Creek (*f*). [No locality recorded for *g*.]

Spatulas (Plate G).

This type of implement consists of a long thin piece of bone one end of which forms a spatulate blade and the rest a grip. In making the spatula a fibula of kangaroo or wallaby has been used in all instances. The fibulae of these animals consist of a shaft and upper and lower expanded ends. The shaft in its lower two-thirds is flattened and crescentic in section, the concave surface being directed medially towards the tibia; but in its upper third it is thicker and more rounded. The middle of the shaft is the thinnest part of the bone and is uniformly concavo-convex in section: It is from this part that the blade is made. Either the upper or lower part of the bone has been used in making the implement so that in one case the grip is more or less rounded and in the other crescentic in section.

The horizontal edge of the blade is rounded off where it meets the sides, and in all but two cases it is also trimmed at an angle, on the concave face, so that the tool has the shape of a gouge. Several of the blades are worn with use.

One implement (*e*) has been made by forming the blade from the head of the fibula, breaking it away obliquely.

The tools range from 112 mm. to 162 mm. long. In nearly all cases the fibulae used are apparently those of *Wallabia rufogrisea frutica*, but fibulae of *Macropus tasmaniensis* were used for making a few of the tools.

The specimens were found at a midden 12 miles south of Cape Sorell (*g*); Rocky Cape midden (*f, j,* and *l*); Tiger Creek (*c* and *d*); and the other seven specimens at Alert Creek.

All the bone implements described above come from a restricted area of Tasmania, the localities being within the area occupied by the western and north-western tribes. Rocky Cape is on the northern coast about 12 miles east of Circular Head and the other localities are on the western coast of Tasmania—Alert Creek, Tiger Creek, and Bottle Creek between Gardiner Point and Sundown Point, just south of the Arthur River; Cape Sorell is the southern point of Macquarie Harbor. Whether this localization is real or merely coincidence can only be shown by systematic examination of Tasmanian middens. The spatulas described by Crowther (1925, 1926) were collected at Little Swanport on the east coast of Tasmania.

Pointed and spatulate bone implements are widespread in Australia.

There are no eyewitness accounts of the use of bone implements by the Tasmanians, so that we can only suggest, from their form, that some of these implements were used as awls, and others perhaps to remove molluscan food from the shell.

Wooden Implements

Two interesting wooden implements were obtained by Mr. James, at the time Head Teacher at the State School, Marrawah, north-western Tasmania. Mr. James provided the following particulars: " The larger waddy was found on the property of Mr. Julius Green, about 3 miles north of the Marrawah School, by his son, Athol, who was removing stumps at the time. This would be about April, 1946. They brought it to me the next day. As soon as possible I went down to the area and examined it carefully. I found the smaller waddy and numerous artefacts . . "

The larger implement (Plate II) is 257 mm. long and weighs 376 grms. It consists of a head and shaft. The head is roughly pear-shaped, the narrower part merging into the shaft. In cross-section the head is irregularly circular, with mean diameter about 72 mm. The shaft is thicker at the end away from the head, this part forming a grip. The diameter of the narrower part of the shaft is about 32 mm. and that of the grip about 36 mm.

The smaller implement (Plate I.) is 193 mm. long and weighs 252 grms. It consists of a head and shaft. The head is bulbous and rather irregular in shape, its mean diameter being about 79 mm. The shaft is short, attached eccentrically to the head,

and is slender in comparison with it. The diameter of the shaft is smallest, about 16 mm., near its junction with the head. At the end away from the head the shaft is expanded as a grip, about 29 mm. in diameter.

The smaller implement is very well preserved, the marks of shaping being quite clear over most of the surface, especially on the shaft. On the surface of the larger implement the marks of shaping are clear in a few areas, but most of the surface is more or less pitted with decay. The implements have apparently been shaped with a metal blade and not with a stone tool. The angles between the cuts are clean, the slices may be quite long, and markings are absent along the cut surface such as should be left by the irregular edge of a stone tool. These features are seen most clearly in the long sweeping cuts on the shaft of the smaller implement (Plate I.).

The use of a metal shaping tool does not invalidate aboriginal manufacture of the material, which seems definite from the circumstances of finding, but it does narrow the period during which the implements could have been made to about 35 years, the period of white contacts with the aborigines of north-western Tasmania. This period began about 1798 when the sealers first visited Bass Strait, passed through the first occupation of land, the Van Diemen's Land Company arriving at Circular Head in 1826, and ended when George Augustus Robinson removed the last of the tribes there in 1834.

Both implements appear to have been shaped from the lower end of the stem of a small tree or large bush, the head from the enlarged mass from which the roots arise (lignotuber) and the shaft from part of the stem above. The wood used for the larger implement is ?*Melaleuca squarrosa* and for the smaller implement ?*Leptospermum* sp.

Both implements balance well in the hand for use as mallets, the smaller particularly so. However, there is no indication of their having been so used, the heads being free from marks of hammering. There is no crushing of the surface wood, the shaping cuts being clear on the heads (where the original surface has not decayed). It is suggested, therefore, that the implements might have been used as throwing clubs in hunting birds and small mammals. Root clubs are a widespread type of implement and were used, for example, by the mainland Australian aboriginal and by the Fijian.

MIDDENS

The systematic examination of Tasmanian aboriginal middens might be expected to yield information on several aspects of the life of those people, perhaps even on the length of time they were resident in Tasmania. With this in view an introductory study, which included some trenching in January, 1938, was made of the middens at Rocky Cape, near Stanley, north-western Tasmania.

The midden examined was a mound of material filling the mouth of a fissure, or cave, in the cliff. This fissure is inclined at an angle of 45-50 deg., and is narrower above. The mound almost fills the mouth of the cave and slopes steeply downwards inside it for about 30 feet; outside, along the front of the cliff, it extends for about the same distance. The depth of material, as found by excavation, was just over 15 feet.

The following observations were made:

(*a*) The midden was essentially a mound of molluscan shells, chiefly the warrener, (*Subninella undulata* Martyn). Shells of the mutton-fish (probably *Notohaliotis ruber* Leach) were much less common and seldom found in some parts of the mound. Also noted were shells of oyster (*Ostrea virescens* Angas), duckbill (*Scutus antipodes* Montfort), mussel (*Mytilus planulatus* Lamarck), limpet (*Cellana limbata* Philippi), volute (*Scaphella undulata* Lamarck), whelk (*Fasciolaria australasia* Perry), and the cart-rut shell (? *Dicathais orbita* Gmelin).

(*b*) Other animal material was represented by a number of bones viz.—

(1) *Gypsophoca tasmanica* Scott and Lord (Tasmanian Fur Seal): The main constituent of the vertebrate remains found in the midden. The bones, from several individuals, included parts of skull and mandible, limbs, ribs, and vertebrae.

(2) *Vombatus ursinus tasmaniensis* Spencer and Kershaw (Tasmanian Wombat): Part of a skull.

(3) ? *Wallabia rufogrisea frutica* Ogilby (Rednecked Wallaby). Portion of the skull of a kangaroo, apparently this species.

(4) *Pseudolabrus* sp. (Parrot Fish). A premaxilla (right) was found at the 12-13 ft. level in the midden.

(c) The mound was black from grime and grease throughout all the upper part; in some places, as against the overhanging cliff wall, shells were charred from fires. There was a distinct lower layer in which the shells were free from ash and grime and merely yellowed from age. In this lower layer also bones were more plentiful.

(d) Worked flakes were very uncommon, the majority of the implements being crudely shaped pieces of the local quartzite without secondary chipping, and there were a few well used hammer stones and many throwing stones. Some bone implements were also found.

(e) There were no stratification layers and no evidence of changed culture, the same types of implements, both of bone and stone, being found throughout.

(f) The finding of remains of a fish in a Tasmanian midden is of much interest, even though we must consider chance occurrence until other material has been found.[2] The few observers who saw the natives in their natural state and who comment on their diet, all say definitely that fish (as opposed to *cray*fish and *shell*fish) were not eaten. It may, however, be of importance that such observations were made on the aborigines of the eastern parts and not on the western and north-western tribes. Different food taboos appear to have existed among the tribes.

The question that must be asked is whether such a fish could have been caught by the natives, if not found washed up on the beach. There is no record of the use of hook and line, or of nets by the Tasmanians. An estuarine fish trap of stones, if ever made by the Tasmanians, would not catch the parrot fish, which lives off rocky coasts.

The habits of the parrot fishes suggest the possibility that they could be caught by the women while seeking the crayfish and molluscs which formed so large a part of the diet. These fish are slow-swimming and lurk in the kelp in shallow water off rocky coasts,

2. Members of the A.N.Z.A.A.S. Anthropology Section Excursion in January, 1949, picked up fish bones on the Rocky Cape site. E. D. Gill has also (*Wild Life*, Oct. 1952, p. 344) found numerous bones of parrot fish in this midden.

N. J. B. Plomley.

where they feed. Under such conditions they could probably be caught in the hands, either by the efforts of one or a group of women, and if not caught directly in the hands they might be forced into the baskets carried by the women when fishing, or be grasped in a mass of kelp in which they were hiding.

Such fish could also be speared from the rocks by the men, or captured by a native thrusting a spear into or under water.

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During December, 1952 the writer, whilst in London, purchased some aboriginal wooden implements, among which was a nobby-ended waddy. This was marked "Tasmania", and was said to have been part of the well-known Oldman collection. It is illustrated in Fig. 2 and is now in the National Museum collection no. 52907.

Its dimensions and weight are as follows:—

Overall length	70 cm. (27·6 ins.).
Length of handle	62 cm. (24·4 ins.).
Diameter of knob	8·7 cm. (3·43 ins.).
Diameter of handle ..	2·2 cm. to 1·6 cm.
Weight	538·5 gm. (19 oz.).

It appears to have been fashioned from a thin shoot of *Leptospermum* or similar type of wood, about 2·5 cm. in diameter, with an enlarged root. The handle is somewhat crooked, and has been roughly reduced in thickness, apparently by means of a stone tool and shows a number of long smooth facets. These could be the result of using a large chipped flake tool grasped in the two hands and planing off the bark and some of the sapwood, with the inner or flat surface of the tool bearing on the surface of the object.

The proximal or handle end is roughened by a series of cross cuts; in this case by using the chipped edge of the tool. The knob end has been finished off possibly by using a piece of coarse grained rock, giving one the impression that a steel rasp had been employed.

A further confirmation of the use of this type of club by the Tasmanians, was the finding of a similar waddy, unearthed from a kitchen-midden at Eaglehawk Neck in Tasmania and described with an illustration in *Walkabout*, November, 1953, by J. A. Fletcher. He states " As far as has been ascertained, there were no aborigines on Tasman Peninsula when the settlement took place in 1830. It must have been before that date that the midden was last occupied by the blacks."

S. R. Mitchell,
Honorary Associate in Anthropology,
National Museum of Victoria.

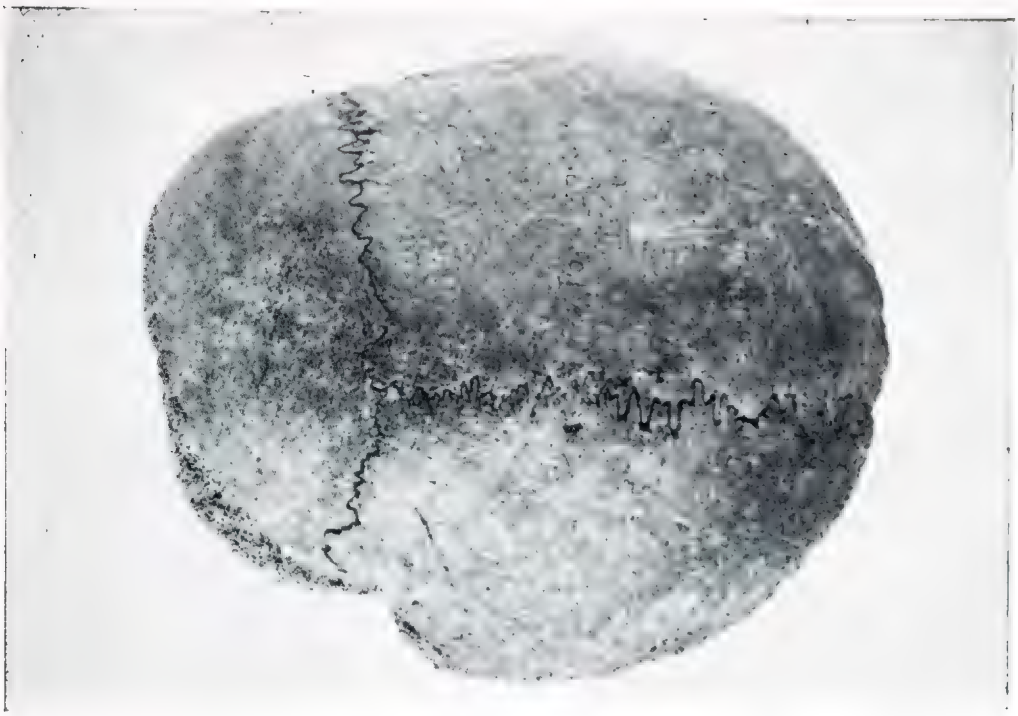


Plate A.

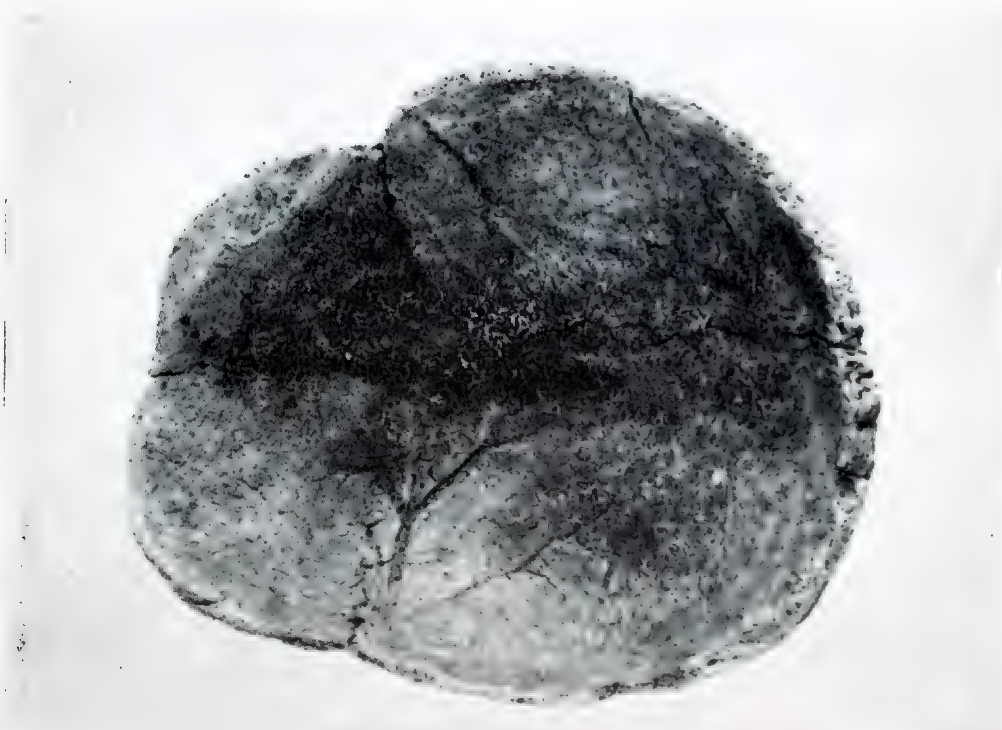


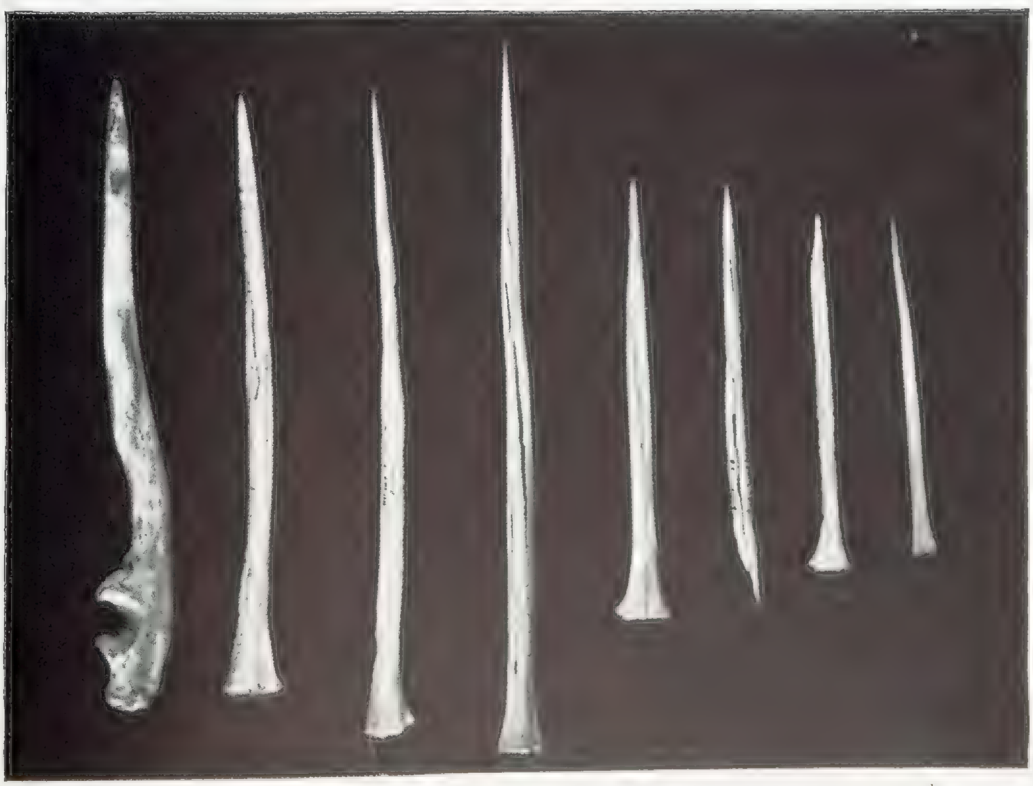
Plate B.

Plate C.

Plate D.

a *b* *c*

PLATE E.



a *b* *c* *d* *e* *f* *g* *h*

PLATE F.

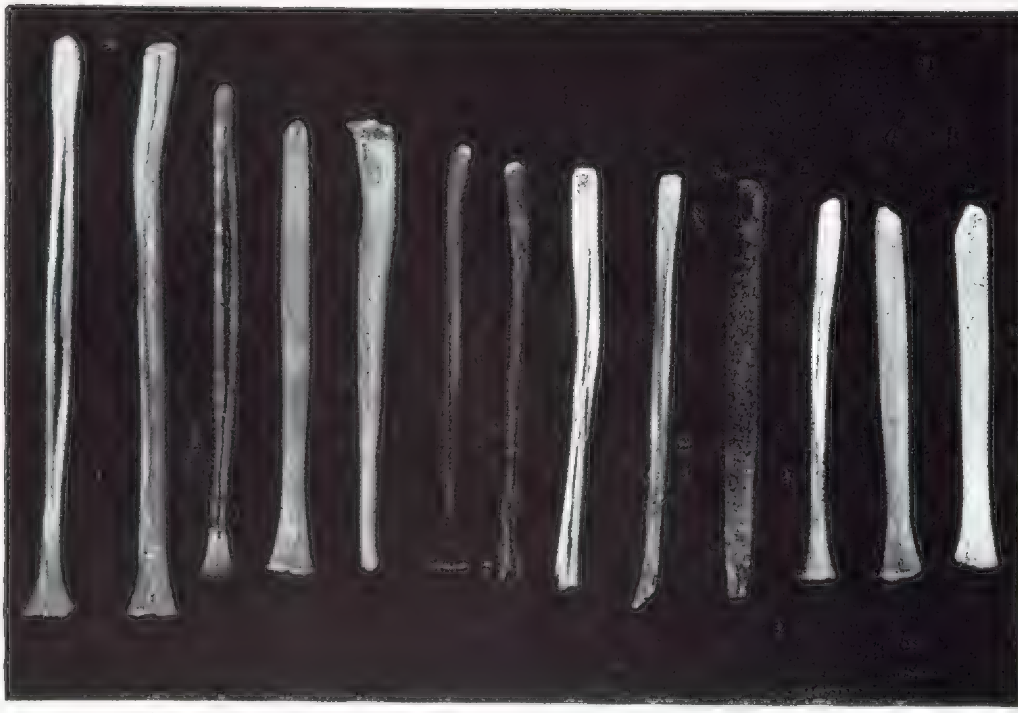


Plate G.

Plate H.

Plate I.

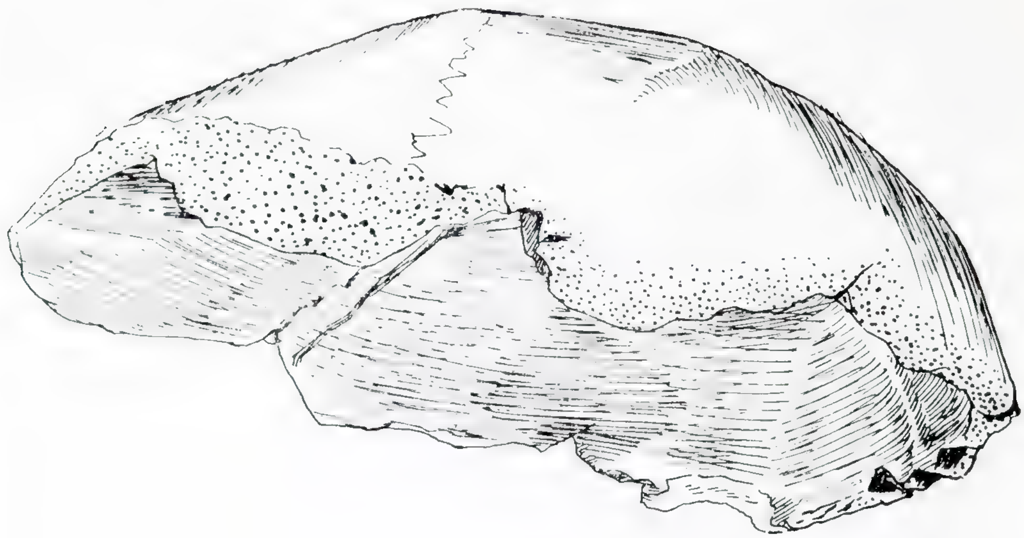


Figure 1.

Figure 2.

ON THE NEW GUINEA TAIPAN.

By K. R. Slater, Port Moresby.

Pseudechis scutellatus was described by Peters[1] in 1867 from a specimen collected at Rockhampton, Queensland, Australia. In 1929 further specimens from Coen, North Queensland, were redescribed by Kinghorn[2] under the name *Oxyuranus maclennoni,* after their collector, W. McLennon. Thomson[3], in 1933, reviewed Kinghorn's paper, and placed *maclennoni* in the synonomy of *scutellatus.* However, he agreed that the cranial and dental pecularities were sufficiently different from *Pseudechis* to warrant the retention of the generic name *Oxyuranus.* Thomson was in error in stating the type locality to be eastern New Guinea, whereas it was actually Queensland, as stated above. Boulenger[4], has recorded New Guinea specimens.

During the past eighteen months several specimens of *Oxyuranus scutellatus* were collected by the writer from the Port Moresby District in Papua. A detailed examination was made, though unfortunately no Australian examples were available for comparison. However, it is obvious that there are some considerable differences in colour, and the keeling of the dorsal and lateral body scales is more pronounced. There is also a difference in the chemical constitution of the venom.

Further, Mr. E. Worrell (personal communication) has prepared a paper for the Royal Zoological Society of New South Wales in which cranial comparisons are made between the two forms. A difference in the shape of the pterygoid as described by him, appears to be sufficiently pronounced for diagnostic use.

The Port Moresby District specimens are very uniform in their colour pattern, and two heads and necks sent from the Fly River area suggest that these individuals, too, conform to the distinctive colouration.

Because of the differences noted above, and, that New Guinea has long been separated from the Australian mainland therefore affording no contact between the two forms in recent times, it is proposed to distinguish the Papuan reptile from the originally described Australian form. It is my pleasure to acknowledge my indebtedness to Mr. George Cann, Curator of Reptiles at Taronga Park Zoo, Sydney, by naming this sub-species after him.

OXYURANUS SCUTELLATUS CANNI SUBSP. NOV.

Papuan Taipan.

Holotype. Nat. Mus. Vic. No. D8614. Collected at Napa Napa, Port Moresby, on August 7, 1953, by K. R. Slater.

Description (3 months prior to death).

Sex:—Female.

Head:—Distinct from neck, moderately long and slender, canthus rostralis positive.

Body:—Elongate, subcylindrical being capable of both compression and depression.

Tail:—Comparatively long, tapering evenly to a fine tip.

Eye:—As large as distance to nostril, one and two-fifths times larger than distance to mouth, pupil round.

Dentition (after death):—Maxillary—large fang followed after space by a single tooth; palatine teeth 5, pterygoid teeth 9 on each side.

Oxyuranus scutellatus canni subsp. nov.

HEAD SHIELDS.

(1) Rostral:—Visible from above, as wide as deep.

(2) Nasal:—Divided by large nostril, $1\frac{1}{2}$ times longer than (3).

(3) Internasal:—Slightly broader than long, $\frac{1}{2}$ length of (6).

(4) Loreal:—Absent.

(5) Preocular:—Single, deeper than long, markedly concave inferiorly and convex superiorly, contacting (6), (8), (2), and 2nd and 3rd of (12).

(6) Prefrontal:—Slightly broader than long, one and one-third times longer than (7), contacting (2), (3), (5), (7), (8), and 2nd of (12).

(7) Frontal:—Lateral margins parallel, $1\frac{3}{4}$ times longer than broad, almost as long as (9).

(8) Supraocular:—Slightly shorter than and almost as wide as (7).

(9) Parietal:—One pair, reasonably large though barely longer than (7).

(10) Postocular:—Two, inferior one the larger.

(11) Temporal:—Five (2 plus 3) inferior of first series largest and almost reaching mouth.

(12) Supralabial:—Six; 3rd and 4th entering eye, 5th and 6th largest.

(13) Infralabial:—Eight; first three contacting anterior pair of (14), 3rd and 4th largest.

(14) Chin shields:—Two pairs, posterior pair slightly the smaller and separated by two gulars.

BODY SCALES.

Dorsal:—Twenty-three rows, imbricate, obliquely arranged, noticeably keeled on neck region whilst keel broadens on body and finally becomes obscure posteriorly; scale series 1 and 23 the largest.

Ventral:—Two hundred and thirty-eight, convex, occupying the entire width of ventral surface.

Gular:—Five series.

Subcaudal:—Seventy-one, all paired, tail complete.

Anal:—Single.

COLOURATION.

Head:—Dark greyish-brown dorsally, lower half of supralabial light-grey, infralabials and underparts whitish.

Body (dorsal):—Ground colour dark greyish-brown, a median vertebral streak of orange—affecting longitudinal scale series 8 to 16 (mid-body)—commencing after first quarter of overall length and occupying the following two quarters whilst becoming narrower posteriorly. Scales within this area are orange anteriorly (particularly so beneath the imbrication) whilst the posterior half of each is invaded by the ground colouration.

Body (ventral):—Silvery grey with faint-orange speckles and the lateral extremities of each ventral being tinged with dark-grey.

Tail (dorsal):—As body ground colouration.

Tail (ventral):—Whitish with each scale faintly rimmed with orange.

Tongue:—Black.

Eye:—Dark-brown with pupil thinly ringed with orange.

MEASUREMENTS.

Overall length:—1,428·7 mms.

(A) Body length	.. ..	1,165·2 mms.	.. ·815 of (O.L.)
(B) Body width	.. ..	27·0 mms.	.. ·023 of (A)
(C) Body depth	.. ..	30·2 mms.	.. ·026 of (A)
(D) Neck width	.. ..	11·1 mms.	.. ·500 of (F)
(E) Head width	.. ..	22·2 mms.	.. ·583 of (G)
(F) Head length	.. ..	38·1 mms.	.. ·027 of (O.L.)
(G) Head depth	.. ..	11·9 mms.	.. ·536 of (F)
(H) Across snout	..	7·1 mms.	.. ·321 of (F)
(I) Between eyes	..	10·3 mms.	.. ·464 of (F)
(J) Eye diameter	..	5·6 mms.	.. ·467 of (H)
(K) Eye to nostril	..	5·6 mms.	.. 1·000 of (K)
(L) Eye to mouth	..	4·0 mms.	.. ·714 of (K)
(M) Tail length	.. ..	225·4 mms.	.. ·158 of (O.L.)

FIELD NOTES

As mentioned earlier, a number of specimens of the New Guinea Taipan have received similar scrutiny to that afforded the type specimen. However, approximately fifteen individuals were seen by the author during the period mentioned. Although the depth of the basic body colouration has shown some variation, the marked vertebral streak was constant in all. The number of scale rows influenced by it varies slightly, making it a little wider or narrower. In some, the orange colour occupies a larger area of each scale than in others and is therefore more vivid.

Papuan natives, living along the coast from the Fly River to the east of Port Moresby, well know the blackish snake with the " red " back, and more than one village has lost an occupant by an encounter with this reptile. It is reported as being abundant in the districts around the mouth of the Fly and the natives of Parama village call it " Dirioro ". Further east at the Vailala River it is locally known as " Gobari ".

When considering the distribution of the sub-species, it must be taken into account that it can exist in many and varied habitats. The type specimen (from Napa Napa) comes from an area well known as " dry ", and indeed without permanent water; a specimen was seen by me from Sogeri, 1,100 feet above sea level; and as before mentioned, the sub-species not uncommon in the Fly delta. The author's personal experience suggests that the Taipan is a shy and retiring snake, preferring flight when encountered, but if interfered with defending itself readily. Speed and accuracy in striking, combined with its great agility, demand in these circumstances, the utmost respect. Any suitable object,

natural or artificial, serves as its shelter—an opening beneath a boulder on a grass covered slope, a hole in a river bank, an overgrown hollow log, amongst debris of old army dumps, or under an old and broken concrete slab; all serve the purpose.

In the past, European residents have not been aware of the true identity of this species and have regarded it as "another kind of black snake". Since its identification, numerous accounts of its occurrence have come to hand and its numbers and range would appear to be greater than was previously supposed. The author's personal observation are that it may be encountered throughout all hours of the day, even while rain is falling, and reliable reports also suggest that it is active after sunset.

Acknowledgments

I wish to thank Dr. F. G. Morgan and Dr. J. J. Graydon of the Commonwealth Serum Laboratories, Melbourne, for the information on the tests made upon *O.s.canni* venom. To Mr. C. W. Brazenor, Assistant Director of the National Museum, I am particularly indebted for his assistance and guidance in this initial effort, and for comparative work carried out. Thanks are also made to Mr. E. Worrell of Woy Woy, N.S.W., for information on cranial comparisons.

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